GEOLOGY OF CHINA

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PREFACE

THE present volume has largely developed out of a part of a series of lectures delivered in British Universities during the years 1934 and 1935, under the auspices of the Universities' China Committee in London. Although a certain amount of material has been added to each of the lectures which are here incorporated in Chapters I-IX, an attempt is made to maintain, as far as possible, the original method of presentation. If I have not failed in my objective, such a method of treatment may prove to be more palatable than presentation in text-book style. To meet the obvious requirements of serious students of Chinese Geology and field workers the essential data of stratigraphy are assembled in Chapter X in a simplified form.

Approaching the subject, as I try to, from the structural point of view, it has been felt necessary to consider the steps by which the basic conception of tectonic forms is arrived at. Comparative study of common tectonic types recognized in China naturally brings the whole world into our view; and in order to pursue the argument to a logical end an exploration into the borderland between Geology and Geophysics becomes inevitable. These aspects of the subject are briefly dealt with, but not without hesitation in a work of this nature.

Phonetic notations are not introduced in spelling the geographical names; for they are too numerous, and, if applied, would only increase the difficulty of reading; moreover, they do not necessarily convey the right pronunciation of the words.

It would be too long a list if I were to enumerate the names of my British friends and colleagues who have contributed illuminating discussions on different parts of the subject-matter. I have, therefore, to be content with a general acknowledgment, inadequate as it is.

My thanks are due to Dr. W. H. Wong, the Director of the Geological Survey of China, for free use of the publications of the Survey, including illustrations, and also to Mr. C. P. Liu, the Director of the Hunan Provincial Geological Survey, for similar reasons. I am indebted to Dr. Arnold Heim for his voluntary supply of valuable information regarding the remote regions of the west and extreme south of China, and to Dr. G. B. Barbour for his frank and friendly discussion on the treacherous problem of Pleistocene Climate. I am under obligation to Dr. L. D. Stamp for his active interest in the publication of this book, and to Messrs. Thomas Murby and Co. for their ready co-operation.

With the limited time at my disposal I could hardly have completed this work without the help of Dr. C. C. Yu in compiling the lists of references, and of Dr. H. D. Thomas, of the British Museum (Natural History), in undertaking the task of reading the proofs and compiling the index. No adequate expression of thanks can compensate for the drudgery of such work. I wish to thank Professor L. J. Wills for his help in many ways, especially for reading my manuscript, with valuable criticisms, of the chapter on Pleistocene Climate in China, and also for granting me the privilege of using the laboratory of the Geological Department of the University of Birmingham in conducting the preliminary experiments with a rotating hemisphere. In this connection I am indebted to Professor W. Cramp, of the Electrical Engineering Department of the same University, for his wise advice in avoiding certain mechanical difficulties incidental to high speed of rotation.

Finally, I must record my gratitude to Professor W. S. Boulton, who, in spite of heavy pressure of his own work, has kindly read through a large part of my manuscripts with many helpful critical remarks. Shortcomings in the sifting and arrangement of material and possible errors are, however, all mine. As one who often has to work under adverse conditions, I should like to mention especially the moral encouragement which I have received from Professor Boulton in carrying on geological research during my college days and ever since.

As the preparation of my manuscripts drew to an end there came the sad news of the loss of a friend and highly valued colleague, Dr. V. K. Ting. It is perhaps not out of place if I take this opportunity to pay a tribute to this man who worked so loyally for the development of geological science in China.

J. S. L.

PUBLISHERS' NOTE

ARRANGEMENTS for the publication of this book were made while Professor Lee was lecturing in England in 1935. In 1936 he was recalled to China. Before he left England he placed in our hands the bulk of his Manuscript, the remainder being forwarded later. Owing to conditions which have since prevailed in China difficulties of communication between the Author and ourselves have caused serious delays.

To expedite the publication of the book, Dr. H. Dighton Thomas, who had undertaken to read the proofs, did much additional work in connection with the bibliographies, arranging for illustrations, and in dealing with numerous queries, which arose from time to time. We and the Author are indebted to him for all he has done in helping to make the publication of the book possible this year.

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July, 1939.

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PART I

CHAPTER I

NATURAL PROVINCES OF CHINA

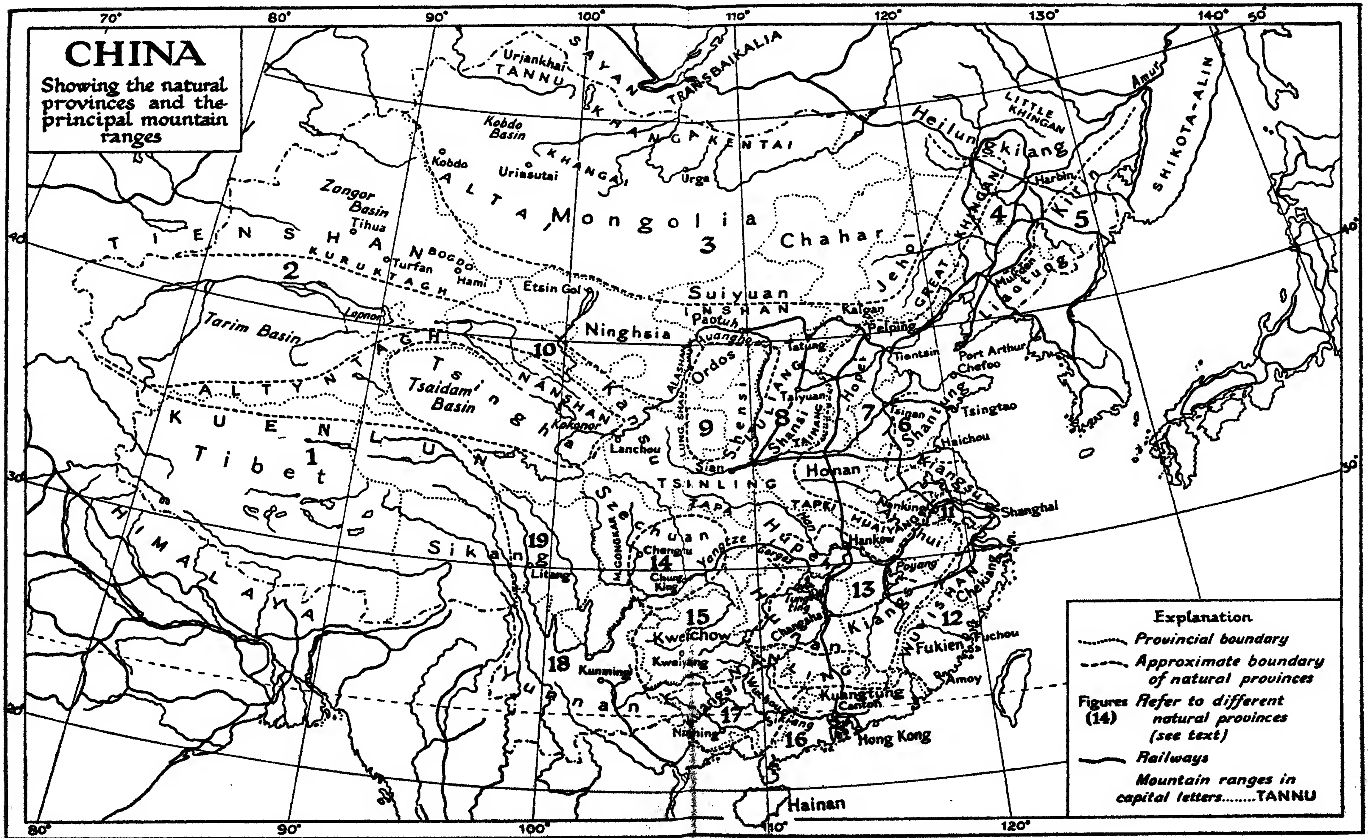
THE physical features of a country represent the sum total of the constructive, deformative and erosive processes that have operated in that country throughout geological time. Surface expression of the physical features often affords useful landmarks for tracing out the evolution of such features. No apology is therefore needed for dealing with the outline of the physical geography of China before we proceed to inquire into its geological history. This procedure seems all the more natural, and perhaps necessary, when we realize that the physical evolution of China has been largely based on a framework that was already laid down in Pre-Cambrian times. The existing features, though they came into existence at much later dates, conform in their general arrangement with that ancient framework.

As viewed in its present relief, China embraces an expanse of land-mass in eastern Asia which half encircles the stupendous massif of Tibet, or " the roof of the world ", forming a staircase, as it were, that generally steps down towards the shelf-seas bordering the Pacific. The staircase does not, however, follow exactly the semi-circular arrangement, but is warped, distorted, shattered and sculptured according to a definite plan. As the stairs recede from the central plateau, their trend markedly departs from the shape of the nuclear platform. A decisive step can be traced across China from the north-east to the south-west consisting of the Great Khingan, the Taihang Range and the eastern border of the Kweichow Plateau. This is followed on the east by a belt of depression covering the Sungari-Liaoho Valley, the great plain of North China and the Central Yangtze Basin. Further east, this depressed area is followed by the notably elevated land-masses of the South-Eastern Highlands of Manchuria and Shantung and of the south-eastern coastal belt embracing the area of southern Chekiang, Fukien and north-eastern Kuangtung.

Across these stretches of elevated and depressed areas are laid, at intervals, mountain ranges or watersheds that run approximately from west to east. Through these mighty ranges China is divided into several latitudinal segments, each of which, speaking generally, becomes more elevated compared with the next one to the south. The northernmost of the west-east ranges within China is the Inshan Range separating Mongolia from northern China. The next to the south is the Tsinling Range forming the natural divide between northern China, or the drainage basin of the Huangho, and the Yangtze Valley. The Nanling Range is the southernmost representative of this group of ranges and separates the valleys of the Sikiang, Peikiang and Tungkiang from the drainage basin of the Yangtze. It is these ranges, together with the Tibetan Plateau standing on the west, that have forced all the mighty rivers of China to flow from the west to the east. It is also these ranges that have naturally sharpened the climatic contrasts and regional differences in other geographical conditions, against which the Chinese have struggled for their unity during historical times through the binding influence of a distinctive culture. Having this broad framework in view, we now proceed to consider the several physiographical units of China, including the adjoining areas.

1. Tibetan Plateau

The pear-shaped mass of Tibet forms a vast plateau over 5,000 m. in average altitude. The whole plateau is surrounded by highly folded mountain ranges on all sides, and is itself traversed by long rows of mountains having their peaks falling in a curved alignment from west to east. Some of the aligned mountain masses well deserve to be


CHINA
Showing the natural provinces and the principal mountain ranges
Explanation
Provincial boundary
Approximate boundary of natural provinces
Figures (14) Refer to different natural provinces (see text)
Railways
Mountain ranges in capital letters........TANNU
TIEN SHAN
KURUK TAGH
BOGDO
ALTAI
TANNU
SAYAN
KHANGAI
KENTAI
TRANSBAIKALIA
GREAT KHINGAN
LITTLE KHINGAN
SHIKOTA-ALIN
ALTYN TAGH
KUEN LUN
NAN SHAN
HIMALAYA
TSINLING
TAPA
TAPEI
HUAIYANG
NAN LING
WU-I-SHAN
LIULIANG
TAIHANG
LUNG SHAN
ALASHAN
IN SHAN
M. GONGKAR
Tibet
Mongolia
Chahar
Jehol
Suiyuan
Ninghsia
Tsinghai
Kansu
Shensi
Shansi
Hopei
Shantung
Honan
Kiangsu
Anhui
Hupeh
Hunan
Kiangsi
Chekiang
Fukien
Kwangtung
Kwangsi
Kweichow
Szechuan
Sikang
Yunnan
Heilungkiang
Kirin
Liaotung
Zongor Basin
Kobdo Basin
Tarim Basin
Tsaidam Basin
Ordos
Kobdo
Uriasutai
Urga
Urjankhai
Tihua
Turfan
Hami
Etsin Gol
Lapnor
Kokonor
Lanchou
Sian
Paotuh
Kalgan
Peiping
Tatung
Taiyuan
Tientsin
Port Arthur
Chefoo
Tsingtao
Tsinan
Haichou
Nanking
Shanghai
Hankow
Poyang
Changsha
Tungting
Chengtu
Chungking
Kweiyang
Kunming
Litang
Nanning
Canton
Hong Kong
Fuchou
Amoy
Mukden
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110°
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20°
FIG. 1

treated as mountain ranges in the ordinary geographical sense. Their geological structure is, however, still ill-understood in most cases. In the northern part of the plateau the ranges run more nearly east-west; but in the southern part the dominant ranges generally follow the Himalayan curve.

The northern border of the plateau is defined by the Kuenlun Range forming a rather sharp step by which the plateau descends to the Tarim and Tsaidam Basins on the north. Several ranges appear on the southern side of the

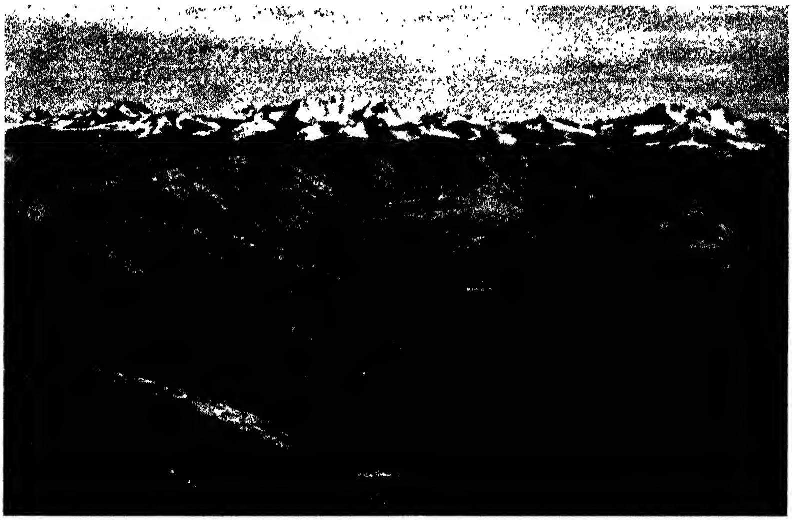


FIG. 2. A general view looking westward of the border of the Tibetan Plateau. (By courtesy of DR. ARNOLD HEIM.)

Kuenlun generally running parallel to the latter. Two of these appear to be quite impressive and persistent in their east-west trend. The northern one is the Kokoshili Mountain, which is probably continued farther east by the Bayen Kara Mountain slightly turned to the south of east. The southern one, even more dominating, is named the Buka Magna Dungburg Mountain. Lesser ranges of similar trend are developed farther south.

On the east, a series of high ranges marks the foreland of the plateau. These are usually styled the "Alps of Sino-Tibet". They curve into the eastern part of the plateau from the western part of Sikang Province and the north-western part of Yunnan, gradually changing their trend from north-north-west to north-west as they enter into the plateau. Ranges allied to these run nearly meridionally in the eastern part of Sikang and north-western Yunnan.

On the southern side, the boundary between Tibet and Himalaya is marked by three ranges partly in linear succession. The western one is the Zaskar Range with the Great Himalaya on its south-western side and the Ladakh

Fig. 3. The town of Litang on the Tibetan Plateau. (By courtesy of Dr. Arnold Heim.)

Range on its north-eastern side running parallel to one another. In the neighbourhood of Lake Manasarowar, the Zaskar joins the Great Himalaya, and is overtaken by the Ladakh. East of Manasarowar, the Ladakh itself marks the boundary of Tibet, extending farther east to the Nepal-Tibet watershed. Thus the eastern extension of the Ladakh, together with the Nepal-Tibet watershed, forms the central part of the southern boundary of the plateau. The eastern part of the boundary lies in the Nyenchen-tang-Lha, an imposing range running east-north-east on the northern side of the upper Brahmaputra.

Some fifty miles north of the Ladakh stands a parallel range named the Kailas, essentially a granite mountain about 20,000 feet high and twenty miles broad. To the north-east of this range and north-west of the Nyenchen-tang-Lha lies a mountainous region defined on the north by the Aling-Kangri Range. This so-called Trans-Himalayan area, about 140 miles wide in its central part, extends between the latitudes of 29° and 31° N. and longitudes 81° and 91° E., with an altitude varying from 17,500 to 19,300 feet. According to Sven Hedin, this region forms the watershed between the Indian Ocean on the south and the enclosed drainage on the north. Irregular masses of mountain dominate the area; and highly complex folding of the rocks characterizes its structure.

The northern and southern boundary ranges and the Himalaya are pressed together in the western end of the Tibetan Plateau, demonstrating the phenomenon of "scharung," or bundling of mountains, on a gigantic scale. The Hindu Kush coming from the west is squeezed into this huge bundle of mountain ranges, and is continued eastward by the famous Karakorum Range stretching into the heart of the Tibetan Plateau. Fossiliferous deposits ranging from Carboniferous to Triassic in age are folded in this mighty range. This and other facts indicate that the plateau has had a more complicated history than is usually supposed.

In spite of a continued desiccation over the whole area, large and small glaciers still exist in the high mountains, and numerous lakes occur in the lower ground. The latter are generally believed to have originated from damming up of the streams by detrital material fallen from the mountain flanks. Earth movement in recent times, however, may have played a part in the formation of some of the lakes.

2. Zongor and Tarim Basins

The province of Sinkiang, or Chinese Turkestan, is divided into two large basins by the Tienshan emerging from Central Asia. The southern, or the Tarim Basin, is largely occupied by the Takla Makan desert in its eastern part. Population tends to gather round places dotted along the margin of the western part of the basin, and especially on the northern side of the Kashgar River, which degenerates into the Tarim River towards the desert region. This basin is almost completely enclosed by mountains on all sides. The southern boundary range, the Kuenlun, becomes almost amalgamated with the northern one, the Tienshan, on the western side of the basin, to the west of Kashgar. The north-eastern boundary is marked by the

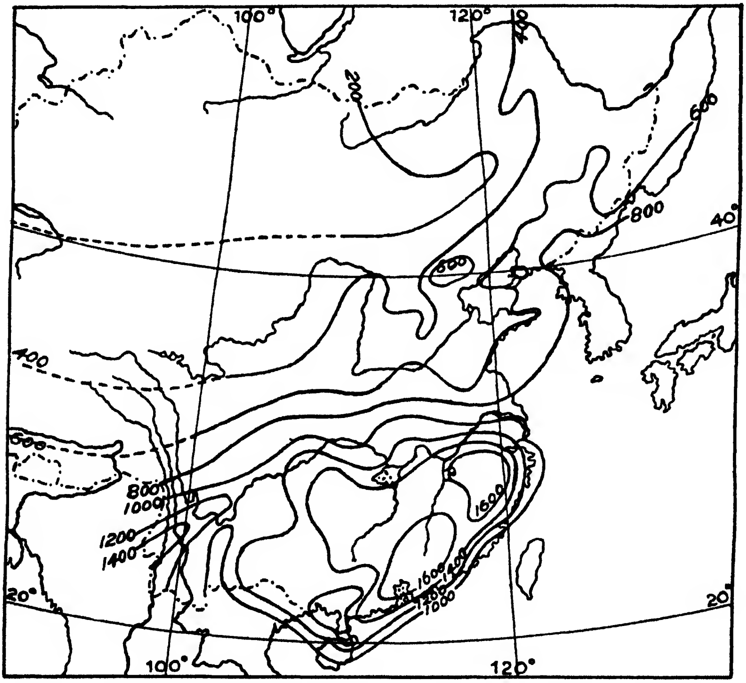


FIG. 4. Mean annual rainfall (in mm.) in different parts of China. (From the New Atlas of China.)

block mountain of the Kuruktagh which forms the south-eastern branch of the Tienshan, and the south-eastern boundary by the Altyntagh which separates the Tarim Basin from the Tsaidam Basin. Between these two mountain ranges there is left a corridor in which runs the highway that leads to the north-western provinces of China proper. Yumenkuan and Tunhuang are among the well-known historic stations along this highway. The latter place is widely known for rich preservation of early historical documents, particularly those of the Tang Dynasty.

The northern, or the Zongor Basin, is more open to the Kirghiz Steppe on the west and to Outer Mongolia on the

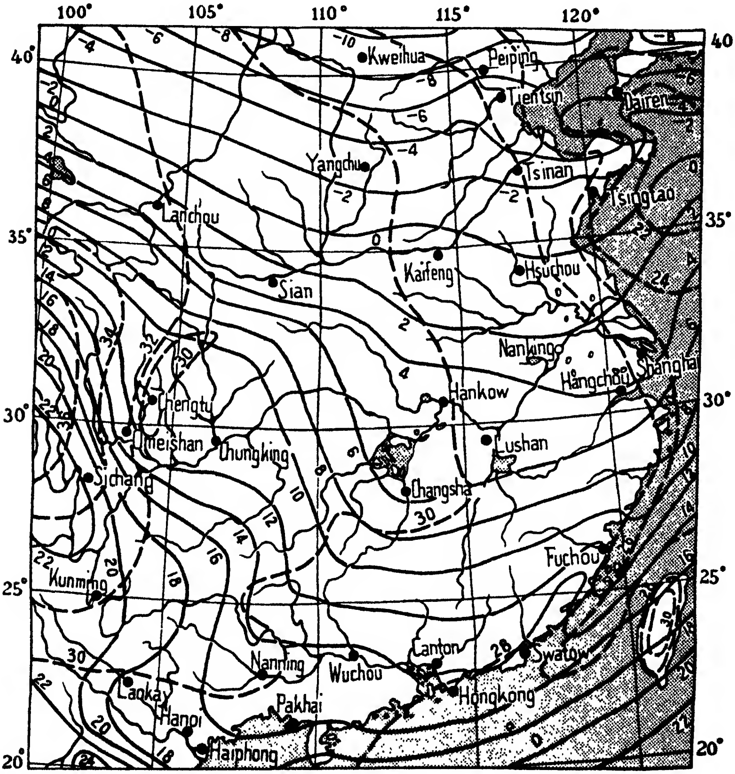


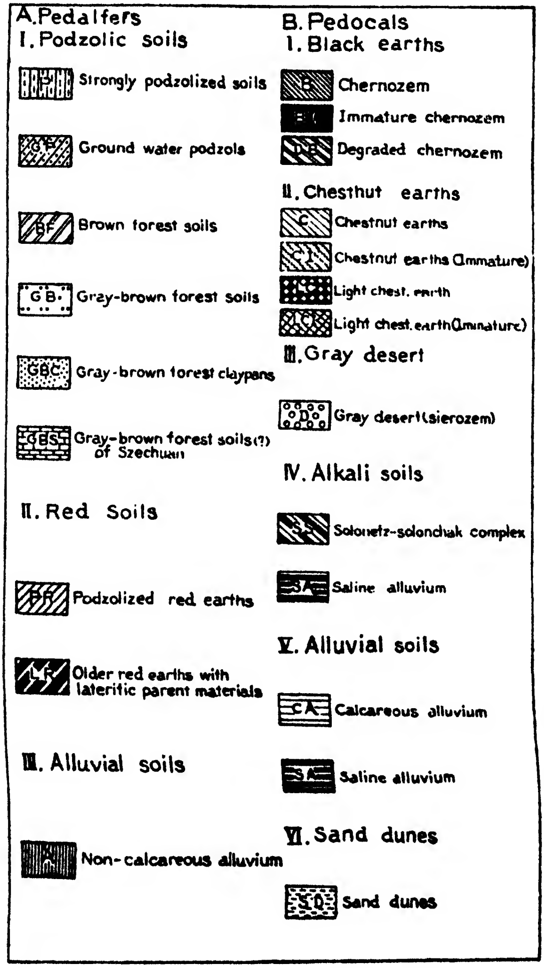
FIG. 5. Distribution of isotherms in China. Full lines indicate the position of January isotherms, broken lines—July isotherms; temperature in degrees centigrade is reduced to sea-level at a gradient of 0·6° C. per 100 m. (After H. VON WISSMAN.)

east. The area is nearly triangular in shape with the Altai Mountains running along its north-eastern side, and with the city of Chenhua situated near the northern apex of the triangle. The eastern portion of the basin is largely occupied by desert land; but the western portion, coming under the benefit of sparse Arctic rain, is quite fit for drifting nomads or even agricultural settlement. At present the

FIG. 6. A tentative soil map of China. (After James Thorp—Geological Survey of China.) For explanation see opposite page.

population is largely distributed along the marginal part of the basin in much the same fashion as in the Tarim Basin. The streams that descend from the Tienshan on the south generally disappear in the desert after travelling for a distance. Those wandering in the north - western part of the basin often feed into a lake. Only a few major streams in the northern part of the basin flow towards the Arctic.

It has been mentioned that the Tienshan sends a branch, the Kuruktagh, towards the east-south-east from its middle part, forming a fork, as it were, that opens towards the east, with the important town of Hami situated in its north-eastern corner. The region enclosed by these fork-like mountains is most striking in its physical aspect. In the heart of this highly elevated continental mass we suddenly find an area nearly quadrilateral in shape, sunk below sea-level. This is



Explanation of FIG. 6.

the Turfan Basin. It might be more properly pictured as a gigantic sink if it had a subterranean drainage.

Communication between the Zongor and the Tarim Basins is maintained by a path which runs from Tihua, the capital of Sinkiang Province, situated on the northern foot of the Tienshan, to a town called Yenchih on the southern foot of the same mountain. The path leads across a somewhat subdued part of the Bogdo Mountains and the Turfan Basin, and rises again before the northern border of the southern basin is reached.

3. Mongolian Steppe

Desert and semi-desert conditions of Sinkiang Province extend eastward over a vast territory generally known as Mongolia. This huge geographical unit is more or less separated from the basin of Sinkiang by rows of mountains arranged *en échelon.* The northernmost of these mountains is the Mongolian Altai Range, which starts from the extreme north-west and extends in a south-easterly direction until it finally disappears almost in the heart of Mongolia. The whole range describes a gentle curve in conformity with that of the Sayan Range further north. The next row to the south is the Bogdo Mountains, or the eastern extension of the Tienshan. The southernmost one is the Kuruktagh, which gradually subsides as it comes into the Mongolian Steppe.

The southern boundary of this steppe land is defined by the Inshan and the Holanshan or Alashan Ranges. The latter, standing on the western side of the Huangho, serves as a natural dividing line between the Ordos region and the Gobi Desert. On the eastern side it is bordered by the Great Khingan, and on the north marked by the Arctic Divide. The whole region is largely peopled by nomads who live in camps or yurlts, as the Mongolians call them, and follow patches of grass and gathering water as nature provides for them. While it is true that the great Gobi Desert spreads over large areas within this raised basin, there exist many tracts of land over which savanna conditions prevail. These less arid districts assume increasing importance as we go northward towards and over the Arctic Divide. Here again the effect of Arctic rain plays an important part.

Numerous local basins exist within this indurated old land-mass or shield. Although it was repeatedly brought under the cover of shallow seas in Palæozoic times, its old floor, probably largely consisting of the great Mongolian Bathylith, is often disclosed on the surface or below a mantle of continental deposits of Mesozoic age. Of the numerous local basins developed in the shield there are two that attain a considerable size. One of these is located in the south-eastern part of the region. The trail between Kalgan and Urga, the capital of Mongolia, runs across this basin from Pangkiang to Irendabasu, a station midway between Taonan and Taolin. The second, which may be named the Hulun-Buyer Basin, is even more extensive, and stretches out behind the Great Khingan dotted with a number of large and small lakes. Although the northern part of this latter basin has been traditionally included in North Manchuria, it bears a much closer geographical affinity to Mongolia. Recent exploration shows that these two basins probably form parts of a vast single basin filled up by late Tertiary deposits.

Toward the " Amphitheatre of Irkutsk " the Mongolian massif ceases to be a shield. A vast stretch of open country is there replaced by mountain folds. They culminate in the Tannu Mountains in the western, the Khangai Mountains in the central, and the Kentai Mountains in the eastern sections, respectively. The western members of this complex system of mountains more or less follow the Sayan trend, namely, south-east, as they proceed towards the east. East of the Selenga River the Sayan trend gives way to the Transbaikalian, *i.e.*, the north-east trend. Then follows the Kentai which runs south of east.

South of the gently convex front of the Tannu lies the basin of Kobdo, while north of the Tannu lies the mountain-locked basin of Uriankhai, triangular in outline. The true Sayan trend becomes manifest in the ranges north of the Uriankhai Basin. These ranges as a whole mark the natural boundary between Mongolia and Siberia. In these ranges lies the so-called Arctic Divide.

4. Manchurian Plain

It has been mentioned that the Mongolian Shield with its raised eastern front descends into Manchuria by a gigantic step. The lowland that stretches out in a north-easterly and south-westerly direction in front of the Great Khingan may be appropriately called the Manchurian Plain, an homologous feature of the North China Plain, to be referred to later. Closer inspection of the area shows that this great stretch of fertile land is sub-divided into two parts by a relatively insignificant divide. The southern area is drained by the Liaoho and its tributaries, and the northern area by the Sungari River which feeds into the Amur River at Tungkiang. These two areas support the largest proportion of the agrarian population of Manchuria.

The northern boundary of the Manchurian Plain is naturally defined by the mountains running north-west and south-east. These are collectively known as the Little Khingan. Towards the south-east these mountains gradually subside, and completely disappear on the western side of the Sungari Valley. Farther east, more mountains arise extending to the north-east. They form the northern boundary of the South-Eastern Highlands of Manchuria. These mountains are not continuous ranges, but are broken through by the Ussuri River which flows northward and joins the Amur River at Khabarovsk. This last named town and also Tungkiang are the important ports in the lower course of the Amur. During the summer season they form flourishing shipping centres, but during the winter the passage is blocked by ice.

5. South-Eastern Highlands of Manchuria

East or south-east of the Manchurian Plain, the country, as a whole, gradually rises in altitude towards the east and south-east. The western boundary of this highland is roughly marked by a line drawn from Harbin, past Yungchih to Mukden. Moderately strong relief prevails in the north-eastern part of this region. The area to the north of the railway connecting Harbin and Vladivostok may be generally regarded as an elevated and denuded peneplain; to the south of that railway line, mountains rise to a considerable height in places. They culminate in the Changposhan towards the northern border of Korea, where the warriors of the early Manchu régime are supposed to have had their home. Farther south, the high relief is gradually transformed into a vast expanse of a denuded and peneplaned old land-mass which becomes lower and narrower towards the south-west to form the Liaotung Peninsula.

6. Shantung Peninsula

On the southern side of the mouth of the Gulf of Peichihli stands the Peninsula of Shantung. This and the opposing Liaotung Peninsula pointing southward are arranged like a pair of pincers; and this arrangement is obviously of vital geographical significance both from a strategic and commercial point of view. It may, indeed, clinch the fate of northern China.

Three important ports have been founded along the coast of the Shantung Peninsula. The northern is Chefoo, which looks across the narrow strait dotted by the Miaotao Islands to Port Arthur, with Dairen as its next neighbour. By a further development of its harbour, its position in the Shantung Peninsula will balance the two ports in the Liaotung Peninsula. Not far removed from the tip of the former peninsula is the port of Weihaiwei. The third port, the most important of the three, is Tsingtao, situated in the southernmost part of the peninsula. Besides the presence of an almost closed inlet of the sea, the Gulf of Kaochou, and natural facilities for harbour engineering, it is already connected by a railway which runs inland and which is joined to one of the trunk lines running north-south at Tsinan, the capital of Shantung Province.

The peninsular area of Shantung is similar to the Liaotung Peninsula in physical aspect. The rivers Kiaho and Weiho which flow northward mark off, in a way, the peninsular area from the main massif of western Shantung. This old, denuded highland is adorned, in its northern part, with the noble mountains of the Taishan, and sinks in its southern part to form a few local basins with a general tendency to subside further south until it comes into northern Kiangsu, where the old massif becomes buried by the alluvial deposit along the abandoned course of the Huangho.

7. North China Plain

After being submerged in the Gulf of Peichihli, the Plain of Manchuria is continued further south-west by another and even more extensive plain, the Plain of North China, covering the whole of the province of Hopei, the western part of Shantung, the greater part of Honan, and the northern part of Anhui. The last named region, together with the northern part of Kiangsu, forms a sub-division or the south-eastern extension of this vast physiographic province. Peculiar geographical conditions prevail over this south-eastern area of the North China Plain. It comes under the influence of the lower Huangho; and at the same time it is often flooded by the Huai River, which has its head-waters in the eastern Tsinling, and which feeds into the lakes in the marshy land near the eastern coast. For this reason, this south-eastern extension of the North China Plain may be called the Huai Flood Plain. This is the only region in which North China conditions and those of the Yangtze Valley become somewhat confluent, particularly in the matter of rainfall. Elsewhere along the Tsinling Range, one finds a sharp contrast in the physical setting and climatic conditions which characterize the countries to the north and south of that range.

The southern boundary of the Huai Flood Plain coincides with the south-eastern boundary of the North China Plain. It is broadly defined by the Huaiyang Mountains, which form an arc with its convex front facing the south. The eastern part of the Huaiyang Ranges is composed of comparatively low mountains rising in groups above the alluvial plain. They stand less than 200 m. above sea-level in their eastern termination, where they are locally known as the Changpaling, north of the city of Chuhsien (about lat. 32° 20′ N., long. 118° 20′ E.) in Kiangsu Province. Proceeding south-westward more or less discontinuously, they gradually rise until they join the Hoshan in the south-western part of Anhui, where they reach an altitude of well over 1,000 m. Thence the mountains sweep round towards the north-west, joining the Tapeishan Range between the provinces of Honan on the north and Hupeh on the south. This Huaiyang arc, as it is known in geological literature, is, in fact, the eastern prolongation of the Tsinling Range. Its full significance will be dealt with when we come to consider the structural pattern of China. At present it will be of interest to note that the sinuous course of the lower Yangtze is primarily controlled by the trend of these mountains.

Reference has been made to the Tapeishan as the eastern part of the Tsinling. It is by this range and its western continuation that the North China Plain is separated from the Central Yangtze Basin, which is a feature homologous to the North China and the Manchurian Plains. Strictly speaking, the Tapeishan does not form a continuous barrier between the North China Plain and the Central Yangtze Basin. At the point (about long. 112° E.), where it joins the main range of the Tsinling, there exists a gap, the Nanyang-Hsiangyang Gap, through which free communication has been maintained between the north and the south. This gap and the eastern part of the Huai Flood Plain constitute geographical features of unusual interest. In historical times, whenever a struggle between northern and southern China was staged as a result of northern invasion, these places were always attacked and defended with considerable vigour.

Turning our attention now to the western boundary of the North China Plain, it seems natural to deal with the question in two parts. Firstly, we will consider the region in western Honan. Here the mountain ranges are divided into two systems. The southern system, of which the Funiu Mountains constitute the dominant members, runs south of east. They suddenly terminate to the north of the Nanyang and Fangcheng districts, forming, as they do, the truncated ends of the central Tsinling. The northern system is composed of the Hiunger and Hiaoshan Mountains, with a general trend north-eastward. These two systems begin to bifurcate in the southern part of Shensi Province, to the east of the longitude of Sian. The eastern ends of these fingers, so to speak, of the mountain ranges mark the western boundary of the North China Plain in Honan Province, namely, the region to the south of the Huangho and north of the Tsinling Range. The whole of this region was known in China throughout historical times as *Chungyuan,* or the Midlands of China. By virtue of its central position its control became a matter of necessity for those who attempted to claim the power of ruling the whole country. History clearly records the fact that this area also served as a centre for the Chinese people and their culture to migrate north-eastward and south-westward, chiefly along the plains in the first stage, and then to spread out all over the country.

The northern section of the western boundary of the North China Plain is marked by the Taihang Range, or the eastern edge of the Shansi Plateau. Starting from the northern side of the Huangho at the point where the river makes a sharp bend like an elbow, this range runs at first north of east, then north-east. Further on, it sweeps round to the north and continues to run in that direction for a considerable distance until it comes to north-western Hopei, where it effects a bend again to the north-east. Finally, it joins the mountains that form the southern border of Jehol Province. The eastern section of the Great Wall is built upon these ranges. Thus it will be realized that the vast Plain of North China is surrounded nearly on all sides by mountains except that part which borders the Gulf of Peichihli. A large area within this plain is subjected to the floods of the fluctuating course of the Huangho and other shallow rivers.

8. Shansi Plateau

Just as the Plain of Manchuria ascends with the gigantic step of the Great Khingan to the Mongolian Steppe on the west, so the North China Plain steps up to the Shansi Plateau along the Taihang Range. In reality this range represents a somewhat deformed edge of the Shansi Plateau, and should therefore be considered as a part of the plateau. The relatively simple features of the range in its south-eastern and middle sections give way to a somewhat complex group of mountains in its north-eastern extension, where they are known in a broad sense as the Western Hills of Peking. These are succeeded farther north-east by the Nankou Mountains and the mountains of the Jehol border.

The western border of the Shansi Plateau is defined by another range, the Luliang Range, which, coming from central Shensi as comparatively insignificant hill-ranges in an east-north-easterly direction, crosses the Huangho at the famous Lungmen Gorge. Thence it turns towards the north-east, and then north-north-east almost parallel with the Taihang Range. As it proceeds northward, the range becomes increasingly imposing. It broadens out, and at the same time rises to a higher altitude. Like its parallel on the eastern edge of the plateau, it bends round from north-north-east to north-east in its north-eastern part. Further north-east, past the famous pass of Yenmenkuan, the range joins the Wutaishan and Hengshan, ultimately becoming confluent with the northern extension of the Taihang Range in the mountains of north-western Hopei and south-eastern Chahar. The Luliang Range may likewise be considered as a part of the Shansi Plateau with a fairly steep front facing the east and a relatively gentle dip-slope towards the west. This range constitutes a true fold-range within the elevated block of Shansi.

A rather narrow and elongated area, through which flows the Fenho, is sunk in the middle part of the plateau. This sunken area, or the Fenho Basin as it has been called, extends from the neighbourhood of the elbow of the Huangho to the north of the city of Taiyuan, the capital of Shansi Province, in a general north-easterly direction. In other words, it follows the trend of the southern part of the Luliang Range. Northward, the central depression of the Shansi Plateau is subdivided into three parts forming three local basins: the Ningwu Basin to the north-west, the Hinchou (Hin-hsien) Basin to the north, and the Pingting

Basin to the north-east. The last-named is located near the eastern border of the plateau with a railway running through it. Although it is the smallest of the three in size, its age-long production of coal and iron has made it famous since time immemorial.

The Shansi Plateau may thus be considered broadly as consisting of three units: the south-eastern table-land, the central basin, and the western and northern mountainous area which steadily slopes down towards the Huangho, flowing from the north to the south. The Tatung Basin, lying to the north of the Luliang Range, and the Paotuh district to the north-west of the same range, may be regarded as the northern and north-western extensions of the plateau respectively. Because of its vast store of coal, and because of its commanding position over the whole territory of northern China, the province of Shansi occupies a position in China, and particularly northern China, that can hardly be over-estimated in its geographical importance.

9. Shensi Basin

The Luliang Range gradually slopes down towards the west into a great elevated plain, which is developed out of a basin filled up by sediments of considerable thickness. The surface of this elevated basin attains an altitude similar to that of the Shansi Plateau. Although it is named the Shensi Basin, it extends in fact into the Ordos region on the north-western, and into eastern Kansu on the western side of the province of Shensi. The Liupanshan, or Lungshan, running nearly north-south in the longitude of 106° E., forms the western boundary of this basin. Northward, the Liupanshan is discontinuously succeeded by the Alashan or Holanshan standing on the western side of the upper Huangho, and the Arbus-ula on the eastern side of the same river. Further north comes the Langshan, which joins, in its northern end, the western continuation of the Inshan Range by effecting a bend towards the north-east.

The southern part of this basin is drained by the Weiho and its tributaries, of which the Chin and Loho are the most important. The southern area in which this drainage system is developed is less arid than the north-western. The latter is practically a semi-desert with an annual rainfall of less than 16 inches. There are large reserves of coal in this basin, though the seams are often deeply buried. Petroleum, salt and gypsum also occur. Their commercial value remains, however, still a matter of uncertainty.

10. KANSU CORRIDOR

To the west of the Liupanshan spreads out a moderately populous area, triangular in shape, defined on the south by the upper Weiho which flows along the northern foot of the Tsinling, on the north-west by the upper Huangho meandering towards the north-east, and on the east by the Liupanshan itself. North of Lanchou, the capital of Kansu Province, a narrow strip of land extends along the northern foot of the high ranges of the Nanshan. Rivers and streamlets, flowing down from the high mountains and due largely to the melting snow, were taken advantage of by the Chinese in past times to develop the only route of communication between China and central Asia. These streams disappear, however, at no great distance as they wander into the desert region towards the north-east, namely, into the province of Ninghsia. The corridor, in which the route runs, stretches towards the north-west between the Peishan and the desert on the one side and the wall-like mountains on the other, with a series of towns, ancient and modern, forming stations along the route.

The route bifurcates at Ansi in the north-western part of the corridor. The one leads towards the west, past Tunhuang and Yumenkuan, the famous westernmost outpost, and then emerges into the desert region of southern Sinkiang, with Lapnor lying near the route. The other leads to Hami to the north-west, and then on to the northern part of Sinkiang. There is yet a third route which is frequented by modern travellers, and which avoids the corridor, but starts from Peilingmiao (about lat. 41° 50′ N. and long. 110° 30′ E.) in Inner Mongolia, to the north of the Inshan Range. It runs westward in the desert region, past Etsin Gol, and finally leads to Hami. With the facility of the Pingsui Railway (Peking-Paotuh) and the development of motor transport, this northern route is likely to assume greater importance in the near future between China proper and the province of Sinkiang.

11. Lower Yangtze Valley

Before reaching the sea, the Yangtze River traverses an area which is sometimes called the Yangtze Delta. Although roughly triangular in shape, this area, essentially of lowland, is not a true delta. Its physiographic evolution clearly proves the erroneous nature of such a conception. The fertility of the soil in this area, together with considerable commercial and industrial activities arising from the development of the port of Shanghai as well as minor centres, makes this region particularly important in the economic life of China to-day. With a commercial influence largely of modern origin is associated an outlook that cannot always be harmonized with the orthodox Chinese culture. A crude type of materialism is rapidly gaining ground, while it also tends to penetrate inland, where the encounter between the indigenous culture and the invading influence is both gruesome and tragic.

Because of the presence of numerous hill-ranges, *e.g.*, the Nanking Hills, rising above the plain, it is rather difficult to draw sharp boundaries so as to define the extent of this geographical unit. Nevertheless, the eastern extension of the Huaiyang arc, such as the Changpaling, north of Chuhsien, stands as a fairly obvious landmark on the northern side of the river. As soon as we cross the Changpaling from the south to the north, we find markedly different conditions prevailing, peculiar to the Huai Flood Plain. The southern boundary of this region can be traced along the northern foot of those hills which characterize the scenery of southern Anhui and northern Chekiang. The Tienmongshan is among the most outstanding of these hills. As the estuarine conditions of the Yangtze are actually felt above the port of Wuhu in southern Anhui, that point may be taken as the apex of this pseudodeltaic area. The lowland districts surrounding Hangchow Bay should be logically regarded as its southern extension.

Within this area lakes are rather numerous. Among them the Taihu is the largest and most important. Rice cultivation and silk industry have been the principal occupations in the economic life of the population. But the latter industry has suffered heavily of late through foreign competition. The enormous amount of imported silk as well as rayon has swept away a greater part of the native industry. Apart from the city of Shanghai, this area has always been renowned for its wealth as compared with any other part of the country. Even under present conditions that position it still holds.

12. South-Eastern Maritime Province or South-Eastern Uplands

In defining the southern boundary of the Lower Yangtze Province reference was made to the hills in northern Chekiang and southern Anhui. These hills or mountains generally extend towards the south-west. Those in the province of Chekiang run more or less continuously into Fukien, with a dominant north-east trend parallel with the coast. With the exception of the Tsientangkiang, which takes a general north-easterly course and feeds into Hangchow Bay, all the other river systems developed in this area have their master stream directed south-east, running across the grain of the country, and are discharged into the sea independently.

Proceeding from the south-eastern coast, which is suggestive of what may be called a pseudo-rias type, towards the interior, the country becomes more and more mountainous in character. These mountains culminate in the long range of the Wuyishan or Shaling, forming the natural divide between the Yangtze Valley and this coastal belt of hilly land. The general trend of the Wuyishan, like the subordinate ranges in the coastal belt itself, is again more or less parallel with the coast. These natural features reflect upon human geography in a striking manner. While the people are now completely under the influence of what is generally known as Chinese culture, they still retain numerous local dialects almost unintelligible to each other and to those who speak mandarin or the common language. The peculiarity of this area will be rendered even more evident when we come to deal with the geological formations and their structure.

13. Central Yangtze Basin

A feature homologous to the North China Plain and the Plain of Manchuria is developed in the Central Yangtze Valley, to the south of the Tsinling Range. This area embraces two lake basins: the Tungting and Poyang, and their adjacent districts. It covers the provinces of Hupeh, Hunan, Kiangsi and a part of southern Anhui, forming a vast depression in central China, as against the Kweichow Plateau and its north-eastern extension on the west and the South-Eastern Uplands on the east. On the north stands the eastern Tsinling, including the Tapeishan and the Huaiyang Range, and on the south there rises the Nanling Range, which forms the natural divide between this area and the Southern Maritime Province of Kuangtung.

Along the western border of the basin a rather abrupt change in scenery takes place. The low-lying country is somewhat suddenly succeeded by fairly imposing highland and mountains. The Yangtze cuts its course across these mountains in western Hupeh, forming cavernous gorges excelling in beauty and grandeur. Similar gorges of a minor scale are also produced in western Hunan by streams such as the head-waters of the Yuan River, which flows into the Tungting Lake. The eastern boundary of the basin is less well defined. Waves of hill-ranges in southern Anhui and south-eastern Kiangsi are propagated towards the South-Eastern Uplands with increasing height, culminating in the Wuyishan and Shaling Ranges which form the divide between the Central Yangtze Basin and the Maritime Province of south-eastern China.

While it is true that the Central Yangtze Basin forms the southern extension of the North China Plain from the tectonic point of view, the minor physical features as well as the physiographic conditions prevailing in these two regions are markedly different. The northern plain is a monotonous plain, being everywhere covered by loess or alluvium. Rainfall, often of a torrential nature, is restricted to the summer season, as generally happens elsewhere in northern China. Continual sunshine prevails throughout the winter. Consequently the shallow rivers that migrate in the North China Plain tend to flood the country during the summer, and become almost dry, in many cases, during the winter.

FIG. 7. The Sintan Gorge, one of the Yangtze Gorges in Central China, looking westward. In the foreground lie disintegrated blocks of Ordovician limestone, followed by Silurian shale in the shrubbed area, then Permian limestones forming the gorge. Faint mountains in the distance are formed by Rhætic and Cretaceous beds.

These conditions are not repeated in the Central Yangtze Basin. There, the country presents a moderate relief with hills and lakes dotted over the whole area. A superficial loamy deposit, apparently equivalent to the loess of the north, is by no means so persistent in its distribution as is thát, however. Besides two maxima of rainfall in June and August associated with the movement of the monsoon, there occurs usually a minor maximum in late winter. Intricate drainage systems developed out of rather complicated local topographical conditions often find their temporary gathering ground in the lake basin, but the overflow of water is usually effectively drained off by the Great River to which the lakes are connected. Only in special circumstances is the overflow of such a volume as to cause devastating floods.

The Central Yangtze Basin is sub-divided into two parts by mountains that separate the waters draining into the Tungting Lake from those feeding the Poyang. These mountains, of which the Kiukungshan, Wukungshan, Wanyangshan and Chukwangshan are among the more prominent ones, form the provincial boundary between Kiangsi on the one hand and Hupeh and Hunan on the other. They do not, however, stand as a complete natural barrier. Free communication between Kiangsi and Hunan is maintained along valleys which run across the succession of these mountains.

Other topographical irregularities arise from the development of several important valleys. In the north-western part of the basin the Han River comes out of the southern foot of the central Tsinling, with a mountainous area on its southern side forming a divide between the upper Han Valley and the Yangtze Valley. This mountainous area of north-western Hupeh is dominated by two mountain systems running east-south-east. The northern, which is the subordinate system, attains its highest altitude in the Wutangshan; and the southern constitutes the Tapashan Range.

In the south-western part of the basin the upper reaches of the Tze and the Yuan Rivers, which feed into the Tungting Lake from the west, are separated from each other by the Sueifengshan; similarly, the upper reaches of the Hsiang and Hsiao Rivers, entering into the Tungting from the south, are divided by the Yangmingshan and Tayishan Ranges, which have a north-north-east trend.

Of all the rivers that enter into the Poyang Lake, the Kangkiang coming from the south is the largest and is usually navigable. The Shukiang and Shangraokiang descend from the hilly region of the south-east, and the Yuanshiu, Kinkiang and Siushiu from the west. The highway between Kiangsi and Hunan runs along the Yuanshiu Valley. Because of the presence of a valuable coalfield in the Pinghsiang district, a railway running along this highway is partially built in order to connect the Canton-Hankow Railway on the one hand and the Shanghai-Hangchow line on the other. The latter section is still under construction.

14. Red Basin of Szechuan

Following the Yangtze upward we come to the western boundary of the Central Yangtze Basin in the western outskirts of the city of Ichang, western Hupeh. There, the basin with its rolling hills and plains is suddenly replaced by fairly high mountains through which the Yangtze cuts precipitous gorges. These Gorge Mountains, as they have been called, extend north-eastward to join the eastern extension of the Tapashan, and south-westward to meet the mountains coming from north-eastern Kweichow and north-western Hunan. To the west of the Gorge Mountains opens out an extensive plain formed by a considerable thickness of red deposit. This is the well-known Red Basin of Szechuan. This vast basin with a succession of young deposits may be considered, in a certain sense, as equivalent to the Shensi Basin in northern China.

The basin is roughly triangular in shape, and is surrounded on all sides by high mountains. The Tapashan stands on the north-east, the Tsinling on the north, the Sikang Ranges on the north-west and west, the Tasiangling, Hsiaosiangling and Taliangshan on the south-west, and the Talushan and Chihyoshan on the south-east. The last-named mountains form, in fact, the north-western border of the Kweichow Plateau. No other geographical unit in China is so clearly defined by natural features as this Basin.

The upper Yangtze, after making a sweeping bend on the northern border of Yunnan, enters the basin from the south-west. It flows along the south-eastern margin of this sunken area towards the north-east, and finally leaves the basin at Wanhsien, a town situated on the western side of the Gorge Mountains. Numerous rivers come from the north to join the Yangtze. Among the more important ones is the Mienkiang, having its head-waters in the Sungpan district on the north-western border of the Basin, and flowing past Chengtu, the capital of Szechuan Province, on its way southward. Running across the central part of the basin there are three main rivers, the Fuhkiang, the Kialingkiang and the Chukiang. All these rivers flow from the north to the south, and become confluent at Hochuan. After travelling for a distance the conjoint flow enters into the Yangtze at the important city of Chungking, the last inland shipping centre along the Yangtze River.

Rows of hills arise from the plain running generally from the north-east to the south-west. They become somewhat crowded in the south-western part of the basin. The known occurrence of coal, salt, and, in some cases, petroleum, for which the Red Basin is renowned, is usually associated with these anticlinal hills. So far as southern China is concerned, none of the other provinces can rival this basin in the matter of natural resources.

15. Kweichow Plateau

Against the sinking land of the Red Basin of Szechuan the Kweichow Plateau rises to the south-east. If we are justified in comparing the Red Basin with the Shensi Basin in northern China, it would be equally justifiable to compare this plateau in southern China with the Shansi Plateau in the north. Although the Kweichow Plateau descends to the Central Yangtze Basin with outstanding topographical features which, if prolonged, would fall in line with, and would therefore appear to be homologous to the Taihang and the Great Khingan, they are, however, not so simple and striking as their northern equivalents.

The north-eastern part of this plateau is somewhat mountainous in character. The mountains, however, soon broaden out as they proceed towards the central part of the plateau. On the south, the plateau is separated from the

Kuangsi Platform by the mid-western Nanling Range, and on the west the South-Western Highlands rise to a still higher altitude.

As in the Shansi Plateau, here in the Kweichow Plateau coal is also widely distributed. But the great misfortune is that few of the coalfields are workable because of the insignificant thickness of the coal-seams.

16. Southern Maritime Province

The province of Kuangtung forms a unit of its own, being characterized by a set of peculiar conditions. It is separated from the Central Yangtze Basin by the Nanling

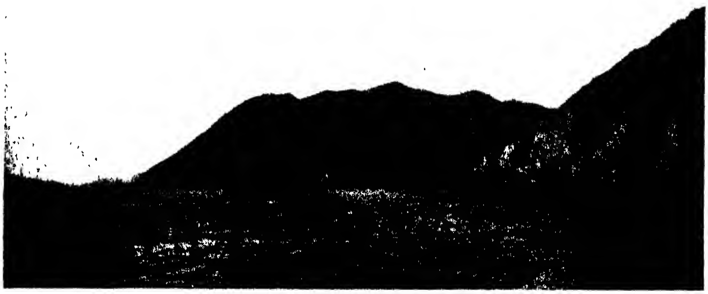


FIG. 8. Drowned valley near Hong Kong. (By courtesy of DR. ARNOLD HEIM.)

Range, which, on the northern border of Kuangtung, is known as the Tayuling. This mountain barrier also marks the boundary between two climatic belts. North of this range temperate climate prevails, south of it the climate is almost sub-tropical. The western part of the province is separated by mountains of the Linshan district from the Kuangsi Platform. In certain respects, the eastern part of this region resembles the southern part of the South-Eastern Maritime Province, namely, the province of Fukien, but there exist notable differences.

The whole area is drained by three large rivers, the Tungkiang, the Peikiang, and the Sikiang, the last-named being the largest. The northern and the north-western parts of the province are fairly strong in relief, with a tendency to subside towards the south. An alluvial plain stretches out from the neighbourhood of Canton, the capital of Kuangtung Province, suggesting the presence of a delta. Careful investigation has, however, shown that the area is not a true delta. Another low-lying area forms the south-western part of the province, including the Neichou Peninsula.

The Isle of Hainan, with a climate almost tropical and a body of aborigines still holding the mountainous part of the country, is developed only along the coastal belt. The wealth of agricultural produce in this island seems to promise a considerable economic importance in the future development of the province of Kuangtung.

17. Kuangsi Platform

Although the province of Kuangsi is connected to Kuangtung by the River Sikiang, so that it therefore comes more or less under the Cantonese influence as far as human geography is concerned, yet this region is comparatively more elevated, and is characterized by an entirely different type of scenery. From the city of Wuchou westward the platform-like country is often studded with clusters of fantastic pinnacles of limestone. In places these pinnacles or karsts occur in great abundance. They are often so exquisite in form and arrangement that they look like a huge piece of rockery in a Chinese garden. Some of the masterpieces of Chinese painting probably have had their origin connected with these curios of Nature.

The Nanling Range describes a sudden bend along the border of south-western Hunan and eastern Kuangsi. There the range, locally known as the Tupangling, runs almost north-south. The Fuho or Kueikiang, together with the River Hsiang in Hunan, forms a continuous waterway connecting the Sikiang and the Yangtze valleys. The Fuho flows between the Tupangling on the east and the Yaoshan on the west. The latter mountain range, still largely inhabited by the Yao tribe, extends from north-north-east to south-south-west for nearly 150 miles. This extraordinary feature represents a slight step by which the eastern part of Kuangsi ascends to the inner and true platform. It is significant that the general trend of the Yaoshan falls in line with the eastern edge of the Kweichow Plateau, the eastern foot of the Gorge Mountains, the Taihang, and the Great Khingan Ranges further north. The inference can hardly be resisted that this feature in Kuangsi is the southernmost member of the homologous series.

FIG. 9. The Karst landscape near Kueilin, Kuangsi.

High ranges of the Nanling stretching nearly east-west form the north-eastern border of Kuangsi. They are broken down on the east at the point where the Tupangling begins to appear. At the junction of the mid-western Nanling and the Tupangling we find again a gap even much narrower than the Nanyang-Hsiangyang Gap which affords a passage from northern China to the Central Yangtze Basin. This Hsiang-kuei Gap, as it may naturally be called, likewise affords the most natural passage between the Central Yangtze Valley and the south-western part of the country.

Westward, the Nanling Range becomes gradually lower, and tends to assume a west-south-west trend, forming the southern border of the Kweichow Plateau. Further west, the Kuangsi Platform merges into the highland of eastern Yunnan much in the same way as does the Kweichow Plateau.

A fairly large basin exists in the south-western part of Kuangsi Province, with the city of Nanning, the capital of the province, situated in the north-eastern part of the basin. A mountain range of moderate height separates this basin from the central platform. Towards the north-west this range extends beyond the Wuming district, and towards the south-east it joins the mountains of the Linshan district in Kuangtung; thence again it stretches into the south-eastern part of Kuangsi to form the Chuluh (Kouluh) Range.

The central platform is traversed by the Liukiang from the north and the Hungshuiho from the north-west. The city of Liuchow on the middle course of the Liukiang is one of unusual interest in connection with human geography. This city is bilingual. It shows clearly the confluence of the Yangtze and *Chungyuan* on the one hand and of the Sikiang or Canton on the other.

18. South-Western Highlands

The common feature that characterizes the highlands of Yunnan is that the high mountains or plateaux are usually deeply incised by active streams. In the north-western part of the country, through which the upper Salween and Lantsangkiang flow southward, the mountains often rise above the snow-line. They may be appropriately regarded as the southern continuation of the Alps of Sino-Tibet. The country gradually slopes down towards the south-east until eventually it becomes transformed into open plains and local basins. Even in the south-eastern part of the country there exist ranges of which the Ailaoshan is one of the most prominent. This range persistently follows the course of the Red River on its south-western side, and runs into French Indo-China.

On the divide between the Kinshakiang, or the upper

Yangtze, and the Red River, the mountains are transversely dissected. And in the transverse valleys a lake is often found standing at a considerable altitude. From these and other facts, it has been suggested that the Kinshakiang probably flowed southward in former times instead of turning to the east as it does now. There seems little doubt that the whole region has undergone a considerable uplifting in relatively recent times. Accompanying the uplifting there have been parts which have broken down. These probably afforded the sites of some of the lakes.

Because of its high altitude, this province as a whole enjoys a congenial climate. It is moreover comparatively rich in natural resources. Aboriginal tribes still constitute an important section of the population. The cultural aspect of the country is practically identical with that of the central and upper Yangtze provinces.

19. Sikang Ranges or the Alps of Sino-Tibet

Little exploration is yet done over this vast mountainous country. The ranges generally run north-south. Some of them, for instance, the Tasuehshan or the Great-Snow-Mountain, south of Tatsienlu, bear permanent snow and glaciers. The Minya Gongkar reaches a height of about 7,500 m. A mountain path leading up from the Red Basin of Szechuan, past Tatsienlu, Patang, and Litang to the Tibetan Plateau is the most important trade route between China proper and Tibet.

China in Historical Times

In closing this chapter it may be of interest to note briefly the influence upon human geography of the natural regions which have been defined. The natural provinces as outlined above essentially agree with the political provinces except in two cases. The one is the province of Kiangsu and the other that of Anhui. A conscious effort seems to have been made in drawing the boundary of these two provinces to counterbalance certain natural advantages and disadvantages.

From a study of mere physical features, one may question whether such widely divergent physiographical units, covering such a vast area, could ever be drawn together to

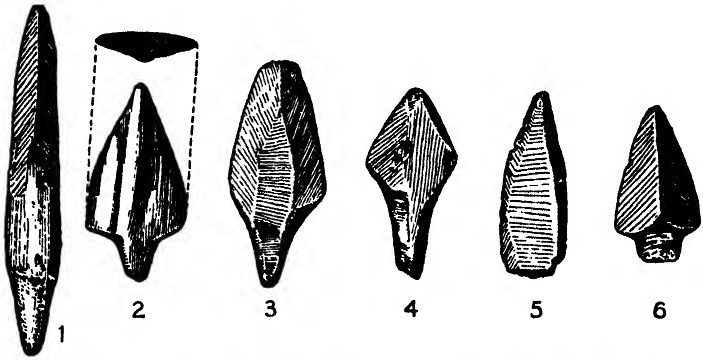


FIG. 10. Six types of stone arrow heads, Yangshao Stage, Yangshaotsun, Mienchihhsien, Honan. × ⅔. (After YOUNG & PEI.)

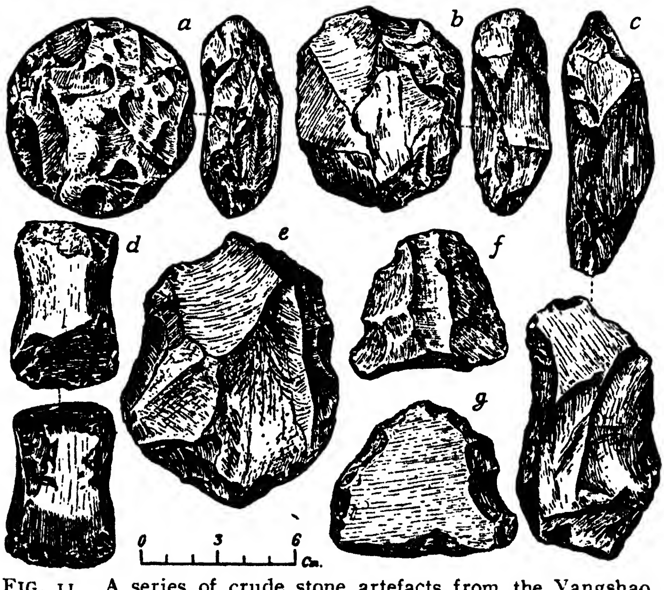


FIG. 11. A series of crude stone artefacts from the Yangshao cultural stratum, Yangshaotsun, Mienchihhsien, Honan. (After YOUNG & PEI.)

form a single geographical entity. The fact that China does exist to-day as a geographical entity has been dealt with at length by Professor P. M. Roxby, who has eloquently explained how the binding influence of a culture has overcome natural barriers. It remains for geographers and historians to trace the steps by which Chinese culture quietly but steadily spread over the whole territory.

The foundation and development of any nation is always a complex process. The Chinese nation proves to be no exception. In the sequel we can only touch upon some of the outstanding facts with a view to elucidating what is involved in the development of China as a geographical entity.

FIG. 12. A well-known type of Yangshao pottery, generally identified with "li" of early historical times.

Archæological investigation in China has brought to light a quantity of material, including arrow-heads, stone axes, and rather crude types of pottery with plain and coloured designs or rope impressions. These artefacts of the Yangshao Age are widely distributed in north-western China and in the central part of northern China. They are also found in South Manchuria. In addition, remains of another type of culture, characterized by thin and black pottery, have been found in Shantung, and are named the Lungshan Cultural Stage from its type-locality, Lungshan, near Tsinan. Although the time-relation between the Yangshao and

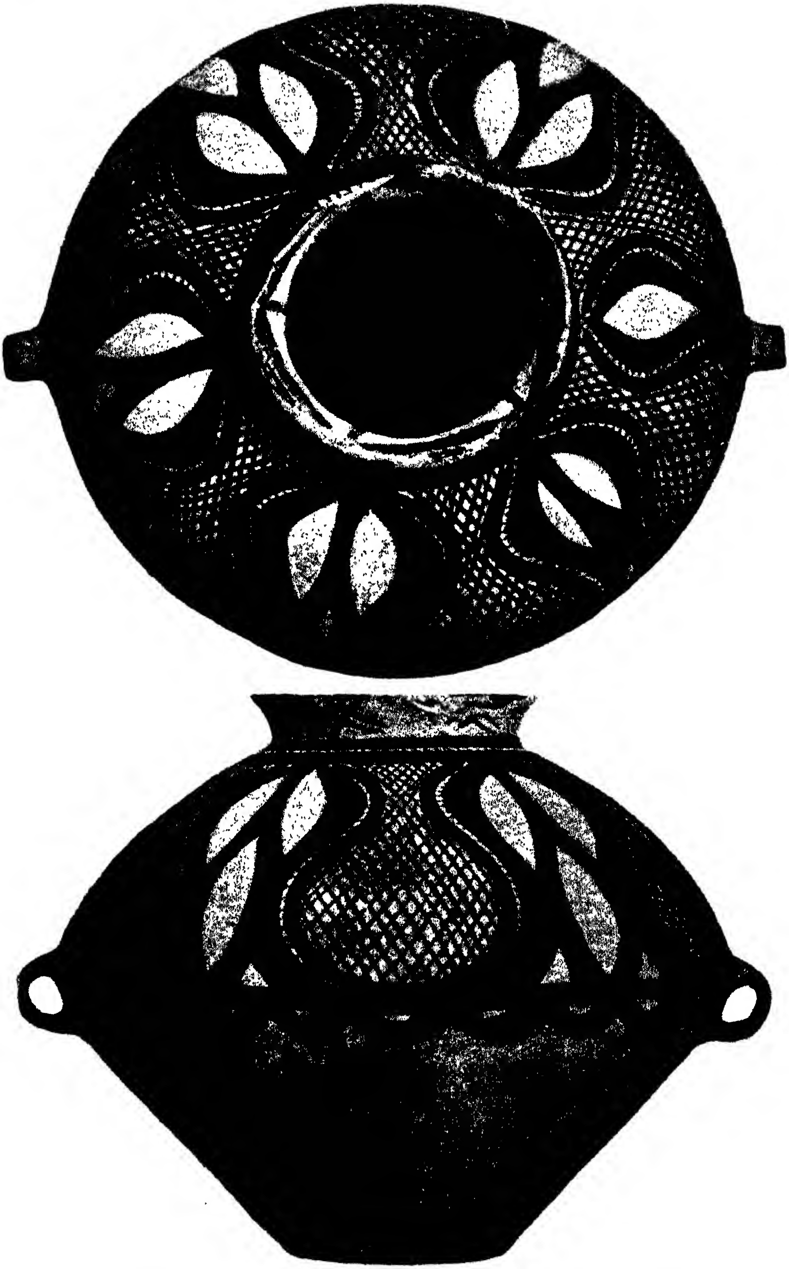


FIG. 13. An urn believed to be of Yangshao Age. (*See opposite page.*)

the Lungshan cultures has not yet been established with certainty,* there is little doubt that they both belong to the late Neolithic age.

Systematic excavation in Anyang, northern Honan, recently carried out by members of the Academia Sinica under the leadership of Dr. Lichi, has located the capital of the Shang Dynasty or people of the Bronze Age. Among the great quantity of material unearthed there are oracle bones, sometimes with inscriptions which confirm certain historical records hitherto regarded by historians as doubtful or legendary.

The presence of buffaloes, rhinoceroses (?) and elephants among the animal remains seems to suggest a climate in these early times somewhat more humid and perhaps warmer than that prevailing to-day in northern China. Otherwise, no positive evidence is available that the physiographical conditions were very different.

It appears true that the early Chinese lived in Central Asia and gradually found their way into northern China through the Kansu Corridor. With the establishment of the Chou Kingdom in the north-west, which later expanded into a dynasty ruling over northern China, the first stage of consolidation of the Chinese as a people was achieved. The feudalistic rule of the emperor gradually degenerated into a nominal control over the numerous states, which sometimes defied the emperor and often fought against one another during the Chunchiu Period in the fifth and fourth centuries B.C. The Chou emperors held a status somewhat similar to that of the popes of the Middle Ages over

* Recent excavations show that the Yangshao antedates the Lungshan.

EXPLANATION OF FIG. 13.

Immediately behind the neck of the urn is a dark-red band running around the neck, with a serrated black band following underneath. Six "flask-shaped" patterns appear in the upper part of the vessel. These are again each surrounded by a plain red band and a serrated black band. The flask-shaped design is filled up with trellis pattern. The dark-red and serrated black bands are considered to be a "death pattern." Contrast this rather advanced type of artefact with the crude stone-implements found on the site of the Yangshao village. About ¼ natural size. Procured by J. G. Andersson from Kansu. Locality unknown. (After J. G. ANDERSSON.)

Christendom. This period of confusion culminated in the Chankuo Period, third Century B.C., when the mightier states, seven in number, had devoured all the minor kingdoms and had actually done away with the emperor. The idea of "Power" which characterizes the world of to-day was

FIG. 14. Types of pottery of the Lungshan cultural stage. Unearthed at Liangchengchen, Erhchaohsien, eastern Shantung. 1, rather rare; 2-4, common types. 1 and 4, natural colour of the clay; 2 and 3, painted black. × ¼. (By special permission of the Research Institute of History and Philology, Academia Sinica.)

literally developed in its full sense. Development of armaments of the ancient type and schemes of political alliances were the principal occupation of the Seven Powers of that time. Ultimately, political alliances for maintaining the balance of power failed, and fighting won the day. The regions involved in this desperate struggle were northern China and a part of the Yangtze Valley—an area approximately equivalent to that of central and western Europe.

With a sweeping military conquest and an intolerably despotic rule, the "First Emperor" of the Tsin Dynasty not only annihilated all the Powers in northern China and the Yangtze Valley, but also built an empire (221 B.C.) which practically covered the whole area of China as it is geographically known to-day. In spite of—perhaps because of—its barbarous effort, this Tsin régime came to an end within a period of less than thirty years. From that time on, peaceful penetration of culture, facilitated by the free migration of the people, steadily strengthened the unifying influence of the whole country. The rule of the succeeding Han Dynasty, lasting nearly five centuries, gave full opportunity for such a development. China as a geographical entity came into being, and the cultural type which was to prevail, with modification, as an essential whole in later ages became definitely set.

FIG. 15. An urn found in the Hsintien burial site, Kansu, representing the "Hsintien Stage" of post-Yangshao and pre-Bronze Age. Note the meander pattern around the neck of the vessel. × 1/6. (After J. G. ANDERSSON.)

In connection with this process of consolidation of China it is to be noticed that certain geographical features were taken advantage of. The focus of early struggles was in the middle part of the Huangho Valley, which occupies the key position in *Chungyuan* or the midlands of China. This was also the area in which ancient Chinese culture attained its height. From this area both the Chinese people and their culture migrated north-eastward and south-westward along the North China Plain. They had already reached the Manchurian Plain in the early Han Dynasty, more than a century B.C. At the same time, they flooded the lower Yangtze Valley across the Huai Flood Plain, and moved south-westward across the Tsinling largely through the Nanyang-Hsiangyang Gap, and, later, across the Nanling through the Hsiang-kuei Gap.

The Manchurian Plain, the North China Plain and the Central Yangtze Basin, which together form the Neocathaysian Geosyncline, constitute, therefore, a region in which the Chinese people with their culture entrenched themselves in the early stage of their development. Thence they steadily pushed southward and south-eastward. As political fortune fluctuated since the Han Dynasty, the forward march of this unifying influence has not been free from adverse experiences from time to time. In the cases of the Three Kingdoms (3rd century) and Five Dynasties (9th century) the country was torn by rival Chinese rulers into several parts more or less along lines of natural divide. This forced division of the people gave rise to ceaseless struggle among their rulers. And such separatist existence struggled on, in each case, only for about half a century.

Another kind of interference arose from northern invasion. An invasion largely from the north-east occurred in the Chin Dynasties (5th to 6th centuries). The whole of northern China, namely, the region to the north of the Tsinling range, was practically torn away, and was independently ruled in rivalry to the southern empire. Another invasion, again from the north-east, was conducted by the Liao and Kin peoples (12th to 13th centuries). The Kin régime established its political authority in northern China with the Tsinling Range as its more stable boundary, although its temporary military successes and failures against the South Sung made this boundary swerve to and fro.

The chronic struggle between the South Sung and Kin régimes had so exhausted both parties that ultimately they were both open to the vigorous attack of the Mongols, who swept down from the steppe land by first crushing the Kin with a conjoint effort of the South Sung, and then the South Sung itself. This was the only occasion in historical times when the whole of China was subjugated to a ruthless foreign rule, lasting for nearly a century (13th to 14th century). But the subsequent nationalistic reaction on the part of the Chinese, the Ming Dynasty, lasted nearly three centuries, and was equally vigorous.

The Manchus came from the north-east more or less as foreign invaders, but they ruled China essentially as Chinese. Therefore they cannot be placed in the same category as the Mongols. The subtle discrimination of political rights shown by the Manchu system of government towards the Chinese and the Manchus, together with the utter impotence of the Manchu régime in coping with a situation created in China by the Powers of the world, brought about the revolutionary outburst in 1911. The movement started from southern China with a distinct tendency to drive northward. National consciousness on the part of the whole Chinese people was probably never so strong in the past as it is to-day when it has been aroused by extremely trying conditions. But the very idea of extreme nationalism as implied in modern totalitarian states is an antithesis of the orthodox Chinese teaching: "Within the four seas all are brethren." The battle between these two extremes has yet to be fought out in China. Would it be true to say that the recent revolutionary movement in China was not, perhaps, as clearly directive as in former periods, because of this national consciousness which has slowly developed in recent times?

But from the purely geographical point of view, historical records make it quite clear that ever since the Han Dynasty the struggle for political supremacy in times of disturbance was either north-centred or south-centred. These northern and southern forces may approach equality in strength: the consequence is a temporary stalemate. And then the Tsinling Range stands out as the line of Rubicon. Each phase of dominating northern rule was followed by a southern reaction. In the case of the Mongolian and Manchu invasions the reaction did not only come from southern China, but from the whole region of China south of the Great Wall also. A lasting peace with stable conditions was only attained when all the natural provinces of

China, north and south alike, entered into the formation of a single state.

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CHAPTER II

THE ANCIENT FLOOR OF CHINA

In the present and the two succeeding chapters we propose to describe the major rock groupings of the country. We begin with rocks which constitute the ancient floor, and it will be convenient to refer to such rocks in the highlands surrounding the existing great basins of China. A formidable sequence of rocks is developed below the Cambrian in different parts of the country. These Pre-Cambrian formations are sometimes considered as a complex group for the reason that they are either unfossiliferous or do not yield such clearly recognizable organic remains as rocks of later ages. The complex nature of the group and the prolonged period of time that it represents can be easily realized from the study of the lithological character of the several formations and the pronounced unconformities that separate them.

So widely do the several formations differ lithologically from one another that, while the lower part is usually metamorphosed beyond recognition, and it is often difficult to say whether the rocks are of sedimentary or igneous origin, the upper part exhibits hardly any petrographical distinction from later sediments. For this reason it is sometimes argued that the uppermost division of the Pre-Cambrian group, namely, the Sinian, should be classified with the Palæozoic. The important stratigraphical boundary, according to this view, does not lie at the base of the Cambrian, but rather at the base of the Sinian. Such a contention is further supported by the fact that a flagrant and universal unconformity exists immediately below the Sinian. Advanced metamorphism in the lower formations ends abruptly at this plane of unconformity; whereas the Sinian usually appears to merge insensibly into the Cambrian. A classification based on these conditions was in fact adopted by von Richthofen, who first established the Sinian System and subdivided it into an upper and a lower part. Richthofen's Upper Sinian comprises the Cambrian and, in some cases, the Ordovician, while his Lower Sinian belongs entirely to the Pre-Cambrian, now known as the Sinian System.

However commendable it may be to consider the Sinian as a part of the Palæozoics from the physical point of view, we are nevertheless confronted with the difficulty arising from formal logic; that is, in the Sinian we have so far found no trace of organic remains showing even a remote relation to the leading life-forms of Cambrian times. It is obviously an unsound treatment to ascribe a formation to the Palæozoic while the absence of Palæozoic fossils still remains a fact.

Unconformably underlying the Sinian is the Wutai System consisting of a mighty sequence of sediments with well-marked stratification. Unlike the Sinian, this system is always more or less highly metamorphosed and frequently penetrated by acid and basic igneous rocks. The Wutai is again separated from the underlying Archæan by a pronounced unconformity. Much still remains to be done regarding the stratigraphical classification of the Archæan rocks. In certain parts of northern China, the excellent development of these ancient rocks promises opportunities for the application of ordinary stratigraphical methods which, when coupled with petrological investigation, may yet yield important results having a bearing on the early chapters of geological history.

A. Archæan

Rocks believed to be of Archæan age are widely exposed in parts of Mongolia, the South-East Highlands of Manchuria, the Liaotung Peninsula, the Shantung massif, the Shansi Plateau, the Inshan Range, the Alashan, the Nanshan Range, the northern belt of the Tsinling Range and its eastern continuation, the eastern part of the Yangtze Gorges, the western part of the South-Eastern Uplands and in a few islands off the Fukien coast, on the southern side

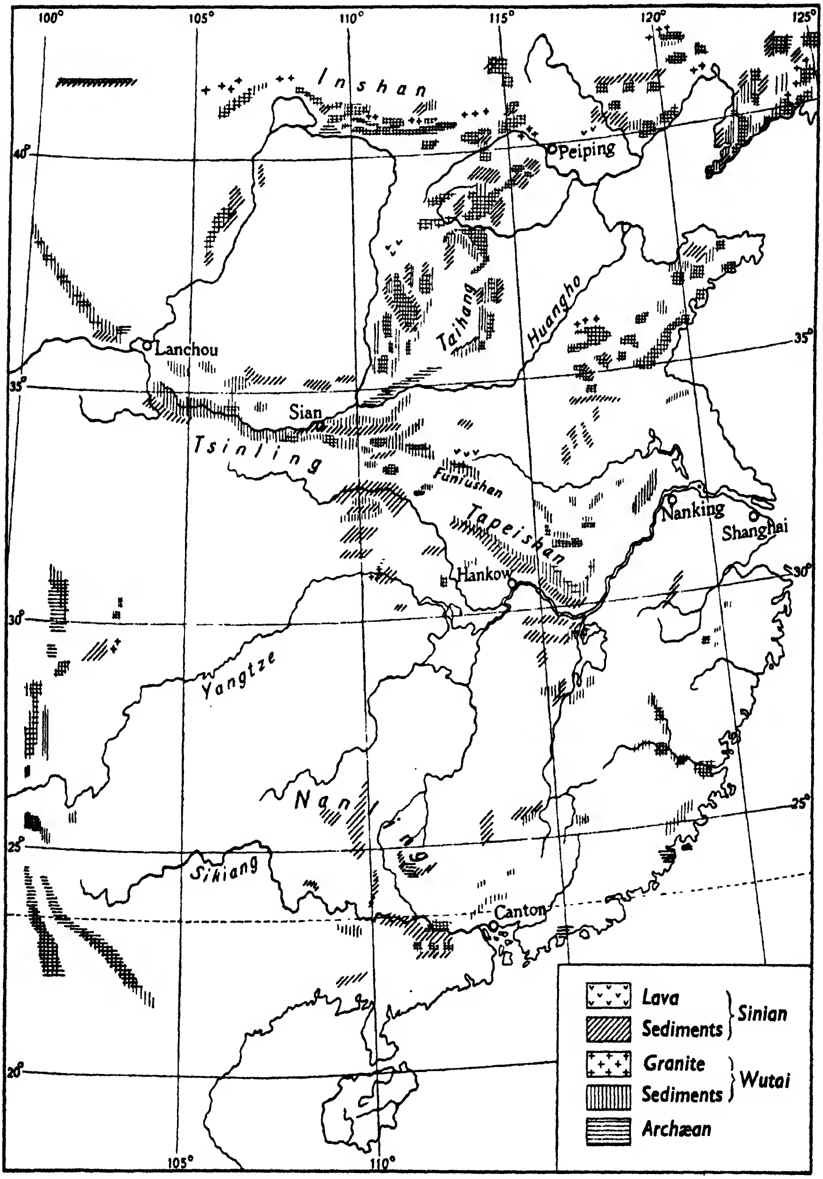

FIG. 16. Map showing the distribution of Pre-Cambrian rocks in China.

of the Sikiang in Kuangtung, in western Yunnan, and in some of the high ranges in the Sikang area.

The best exposures of Archæan rocks so far recorded are those occurring in the Shansi Plateau. A fairly large area of Archæan gneisses and schists occurs in the neighbourhood of the Fenghuangshan, on the southern border of the plateau, to the south-east of Kianghsien. A smaller mass of Archæan rocks forms the Hoshan, east of Hohsien, and is capped by Palæozoic sediments. In the western part of the plateau, the main range of the Luliangshan is largely composed of the Archæan, having a width of more than 50 km. Starting from the northern side of the lower Fenho, this belt of the Archæan runs almost continuously for nearly 240 km. to the north-north-east.

Observations made by C. C. Sun along the western flank of the northern Luliang Range have established stratigraphical facts of importance. For tens of kilometres a clean unconformable contact between the Wutai System and the Archæan was traced along the flank of the mountains to the south-south-west of Fangshanhsien. The Archæan gneiss is a coarse-grained, dark-grey rock consisting chiefly of white felspars, black biotite, hornblende and quartz, with biotite often more predominating. The foliation planes of the gneiss are often invaded by large and small bands of granite which varies in colour and texture—from reddish-grey to pink, and from fine-grained varieties to those as coarse as pegmatite. The coarse varieties are generally massive and homogeneous. The gneiss is also invaded by amphibolite and other basic rocks probably of post-Archæan age. None of the massive granite bands reaches the Wutai, although the latter shows foliation parallel to that of the gneiss.

Towards the central part of the range, a medium-grained reddish-grey granite becomes the prevailing rock with reddish and grey felspars, light brown quartz and dark biotite. In the granite often occur aplitic and pegmatitic veins believed to be differentiation-products. Towards the higher levels the granite becomes coarser in texture, grading into pegmatite. Although essentially homogeneous in composition, it is locally penetrated by well-defined lenses and dykes of amphibolite, and is sometimes foliated or gneissoid in structure.

In the neighbourhood of the village of Suchiawan, about 75 km. west-north-west of Chiaochenghsien (about 112° 10′ E., 37° 35′ N.), an extensive inlier of a coarse-grained, white, dolomitic marble occurs within the area of the Archæan granite. This dolomite-marble is invaded by dykes and veins of the granite. Smaller masses of the marble were also observed in the same district completely surrounded by the granite. If the granite is connected with the Archæan masses occurring along the western flank of the Luliang Range, as it appears to be, then this marble must be also of Archæan age.

More important is the exposure of Archæan rocks in the north-eastern part of the Shansi Plateau, covering the country around the Wutaishan and extending along the Taiholing and the Fuping and Tanghsien districts in north-western Hopei. In the classical locality, Taiholing, Sun recognizes four groups of rocks entering into the composition of the Archæan complex: (1) the ancient gneisses and schists, (2) granites, (3) metamorphosed stratified rocks, and (4) basic igneous rocks.

Group (1) embodies essentially a medium-grained hornblende-gneiss composed of hornblende, plagioclase and quartz, with biotite and other accessory minerals. Sometimes biotite predominates among the dark constituents, and sometimes felspars and quartz form the bulk of the rock, giving it a light colour. Segregated layers of biotite-schist frequently alternate with the gneiss so that the rock assumes a banded appearance. Irregular patches of amphibolite present in the gneiss, together with occasional pegmatite veins, mark further structural complication in the complex. The bands are often contorted and laterally compressed, giving rise to a puckered arrangement. Similar rocks are exposed in the Tanghsien district, as has been described by E. Blackwelder.

Group (2) includes several types of granite of different generations. The oldest is a group of gneissoid granites, generally of medium-grain, varying in colour from grey to red according to the amount of pink felspar present. These old granites occur both as large bathylithic bodies and as minor intrusions. In the latter case, the ancient gneiss which is invaded by them often becomes so thoroughly impregnated by the igneous material that it is literally soaked by the granites. At the same time, the invading granites are drawn out, forming contorted bands, irregular lenses and puckered structures. The foliation-plane or plane of banding in the ancient gneiss and schist at the contact with the granites is usually taken advantage of by the injected rocks which form small lenses, strings, streaks and veneers. These are cut across by veins of pegmatite and aplite.

Group (3) occupies, according to Sun, the central part of the Taiholing. The rocks are essentially foliated hornblende-felspar-amphibolite, hornblende-amphibolite, dark grey gneiss, slaty biotite-gneiss and biotite-gneiss with alternating bands of amphibolite. These rocks show a marked stratigraphical sequence, and appear to form a closed syncline according to the same observer, who points out that crystalline limestone under the influence of a granitic intrusion may change into hornblende-felspar-amphibolite.

To group (4) are assigned amphibolites. They occur as inclusions and intrusions in the gneissoid granites, and as bands and layers in the hornblende-felspar-amphibolite or biotite-gneiss of group (3). The rock is usually composed of hornblende with little felspar, but covers many varieties. They are obviously of different origin. Those which cut across the granites and gneisses in the form of dykes and irregularly shaped masses are clearly of igneous origin. Others which are embedded in gneissoid granite, or in a mixed rock of gneissoid granite and ancient gneiss, are believed to be fragments of an already consolidated rock which have been torn off by the granitic and gneissic intrusions; for lenses or other irregularly shaped masses of amphibolite lying in contact with the ancient gneiss are sometimes found to be surrounded by fluxion structure, and sometimes invaded by the gneissic granite along the plane of contact. In the latter case, a few veins of the gneissic granite penetrate into the amphibolite, whereas the gneiss is simply soaked by the granite.

This fourfold division marks an important initial step in the classification of the Archæan rocks in the Taiholing. The area well deserves a still fuller investigation. In this part of the Shansi Plateau, the Archæan extends along the south-eastern side of the Wutaishan, where the prevailing rock is a biotite-gneiss grading into mica-schists. It is believed to be unconformably overlain by the basal member of the Wutai System in the neighbourhood of Shitsui, but the unconformable contact has never been actually observed.

On the northern side of the Wutaishan, the country is almost entirely occupied by a reddish gneissic granite, described by Richthofen and apparently comparable with some of the granites recognized by Sun in the Taiholing under group (2). It was named Sangkan Gneiss by Richthofen, who considered it as younger Archæan and extended the usage of this term to the north-eastern part of the Kalgan area. After a careful study of the latter area, G. B. Barbour accepts Richthofen's nomenclature and correlation, and remarks that the general composition of the rock varies from arkose quartzite to garnetiferous hornblende-schist. The remarkable character of the Archæan in the Kalgan area is that the whole sequence of the highly metamorphosed rocks shows a wonderfully well-preserved stratification. The bulk of the material is undoubtedly of sedimentary origin, though numerous igneous intrusions, particularly of the basic type, occur along the bedding planes. For the latter reason, the whole Archæan mass presents a well-bedded appearance.

A core of Archæan rocks is believed to be present in the southern part of the Taihang anticline, south of the Chengtai Railway. Actual exposures are, however, only few in number, and each is restricted in areal extension. On the western side of the Lingcheng coalfield a red granitoid gneiss traversed by numerous quartz veins is exposed for a distance of about 2 miles. It is overlain by Sinian quartzite. Somewhat more extensive are the exposures in the north-western part of Wuanhsien and in the western part of

Linghsien further south. In these places, the gneiss is generally a medium-grained rock, often highly micaceous, and is associated with mica-schist. Its unconformable contact with the overlying Sinian formation is particularly well exposed in the Wuan district.

In the western part of the Shantung massif, Blackwelder describes the Archæan under the term Taishan Complex, on account of the fact that these ancient rocks form the noble mountain Taishan. They are composed of gneisses and schists penetrated by bodies of granite and dykes. As developed in the type locality, the Taishan, the rock is largely a banded grey gneiss of medium grain and granitoid composition. The principal minerals are quartz, orthoclase and biotite. Hornblende or chlorite also abounds in certain phases. In association with the gneiss are schists, more or less well cleaved, and usually composed of quartz and hornblende, which may sometimes be accompanied by biotite.

An extensive belt of Archæan rocks is exposed in the eastern part of the Shantung Peninsula. The southernmost part of this belt reaches the Haichow district, north-eastern Kiangsu, forming low hill-ranges between that part of Kiangsu Province and Shantung. On the southern side of the city of Haichow the Archæan is largely composed of a granitoid biotite gneiss with occasional inclusions of amphibolite, and usually free of pegmatite and quartz veins. In the north-western part of Haichow and in the Kangyu district, the biotite-gneiss becomes, however, highly schistose, and is frequently penetrated by pegmatites and a network of quartz-veins.

These rocks probably extend north-eastwards along the coast until they appear on the south-western side of Kiaochow Bay. From the city of Tsingtao, the Archæan continues to run to the north-east, reaching the head-waters of the Kuho, south of Chefoo. The rock is generally of coarse texture with white and pink felspars, granular quartz and relatively abundant hornblende. Irregular segregates of biotite, not infrequently altered to chlorite, occasionally occur in rude parallelism, giving rise to a coarsely banded structure. Otherwise, the gneissic structure of the rock is by no means pronounced. The whole mass is often traversed by numerous veins of pegmatite and quartz, the latter being sometimes auriferous. In places, this gneissoid granite is unconformably overlain by the Wutai System, thus confirming its Archæan age.

Rocks believed to be Archæan in age are exposed in the Liaotung Peninsula, for instance, in the Siungyue district. They disappear northward, but reappear further north between the districts of Sihan and Sihfeng, where the Archæan schist is a brownish-grey, fine-grained rock with well-developed schistosity. Quartz and pink felspar are the principal mineral constituents. Biotite is also present in subordinate amount. Large crystals of pink felspar are often so abundant that the whole rock is rendered pinkish in colour. Similar rocks discontinuously extend still further north. The Archæan belt exposed in the Tangyuan district along the lower Sungari River apparently falls in line with the north-north-easterly extension of these exposures.

More extensive are the exposures of Archæan gneisses and schists in the axial and frontal parts of the Great Khingan Range. In the axial part of the range, as well as in the Malanyu anticline on the southern border of Jehol where the Great Wall stands, the Archæan begins with a thick sequence of amphibolitic strata, followed by mica-schists, gneisses and laminated porphyritic granites. These are apparently intruded by biotite-granite and by pegmatite-granite containing auriferous quartz veins of younger age. Along the front of the range the exposure of the Archæan rocks is much less persistent. In the neighbourhood of Hulutao, Archæan granite, rather coarse in texture and pink in colour, forms a cliff along the southern coast. The rock is traversed by numerous dykes, and is unconformably overlain by Sinian quartzite. Along the same strike, but farther to the north-east, a medium-grained granitoid gneiss is widely exposed in the coalfields of Fuhsinhsien and Pataohao. Here, the true Archæan gneiss is frequently invaded by coarse granites and pegmatite as well as dykes and sheets of basic rocks. These are associated with schists and quartzites believed to be of Wutai age.

Much further north-east, and still along the same strike, several broad exposures of the Archæan are distributed in the middle part of the Nonni Valley (between lat. 48° 30′ and 49° 30′ N., and long. 124° 10′ and 125° 50′ E.). In this area the Archæan forms bold ridges or even high mountains. The rock is usually light brown or yellow in colour, and only occasionally exhibits gneissic structure. It is sometimes invaded by granite masses in which are included masses of a dark rock rich in biotite and with sporadic phenocrysts of felspar. This complex is unconformably overlain by a quartzite supposed to be of Sinian age. Archæan rocks are probably present in the Little Khingan Range to the north and north-east of this area.

A complex group of gneisses, schists and crystalline limestones, penetrated and saturated by igneous material, forms the block mountains to the south and south-west of Tsetsenwan in Mongolia. Because of their great structural complexity and the intense metamorphism to which they have been subjected, Berkey and Morris refer these rocks to the Taishan complex. The presence of limestones reminds us of the Suchiawan dolomitic marble in western Shansi.

On the southern border of the Mongolian steppe the Archæan complex makes a grand display along the Inshan Range. As mapped and described by C. C. Sun the ancient gneisses, schists, and marbles occupy extensive areas in Suiyuan Province, forming the Ulashan, Sheitenula, a large part of the Tachingshan, and the Kueitengliang. From the last-named range it extends southward into the province of Shansi, and to the north-west for an unknown distance. In south-western Chahar the Archæan gneisses and schists are exposed between the Huaian and Hsingho districts, extending south-eastward to the country drained by the upper Yangho, where Richthofen first described his Sangkan Gneiss.

In these ranges the Archæan can be broadly divided into two types. The acid gneiss of granitoid composition is usually more or less well-bedded, sometimes containing rounded grains of quartz showing incipient resorption. With the bedded gneisses are often interstratified thick and thin beds of marble. In the Ulashan the marble reaches a thickness of 150 m. Usually it is much thinner, however, and is often traversed by veins of asbestos. Seams of graphite are sometimes intercalated in the gneiss. They are of some economic importance in the Siyangho area, west of Kalgan. The gneiss is frequently thoroughly soaked by granite, particularly along its bedding planes. The resulting rock is a mixture of gneiss and granite sometimes named migmatite. The acid gneiss is clearly of sedimentary origin.

The basic gneiss is usually an amphibolite with hornblende dominating. It grades into mica-schist or chlorite-schist in places. Pyroxene sometimes abounds, when the rock may be called hornblende-pyroxenite. These basic gneisses are usually injected into the acid gneiss along the bedding planes. They are therefore believed to be of igneous origin. The whole range of the Sheitenula is composed of these basic rocks, except for its southern slope where the bedded acid gneiss with layers of marble is developed in the usual way. In several localities these acid and basic gneisses are unconformably overlain by the Wutai System, though they are often penetrated by post-Wutai intrusions.

Archæan rocks of the Inshan type are probably involved in the Alashan on the western side of the upper Huangho. So far, however, no detailed examination has been made. The marmorized limestone exposed on the eastern side of the Arbus-ula in association with a granite, as observed by Teilhard and Licent, and believed by them to be of Wutai age, may eventually prove to be the equivalent of the Archæan marble in the Inshan Range.

Farther south along the strike of the Alashan and in the south-eastern prolongation of the Nanshan Ranges, T. F. Hou and C. C. Sun found, in the north-western part of Lanchou, a group of gneisses, granite and schists involved in complicated folding, and overlain by the Nanshan Series of Hsieh or Nanshan Sandstone of Loczy. Hou and Sun regard the gneisses and schists as Archæan, and compare them with the Sangkan Gneiss.

In the Nanshan Ranges themselves gneisses and schists are mentioned by Loczy and Obrutchev as Archæan.

They do not seem to have detected in these high ranges any crystalline axis. In view of the fact that tabulate corals, such as *Pachypora* and *Favosites,* have been found in the limestone which forms the upper part of the highly metamorphosed Nanshan Series, it is obviously unsafe to assign an Archæan age to the gneisses and schists occurring in the Nanshan Ranges. Hsieh maps a zone of gneiss probably of Archæan age extending from the neighbourhood of Tienshui (about 34° 30′ N. and 105° 45′ E.) to the vicinity of Lanchou (about 36° N. and 103° 40′ E.). This zone, if prolonged to the north-west, would cut obliquely across the south-eastern part of the Nanshan Ranges, and would run into the Kokonor region.

Along the northern part of the western Tsinling Range Y. T. Chao and T. K. Huang observed a narrow belt of highly metamorphosed rocks, chiefly granitoid gneiss and mica-schist, overlain by Palæozoic formations. After summarizing their own observations and comparing them with those of the earlier observers, Huang came to the conclusion that the two types of rocks form an intimately connected system, the Tsinling System, and cannot be separated into two formations of different ages. Huang compares the Tsinling System with the Sangkan Gneiss, but points out distinct differences in lithological character. In the Sangkan Gneiss, as developed in its type locality, there is no crystalline limestone, but in the Tsinling System marble is sometimes present. The gneiss sometimes merges into genuine granite, and is apparently intercalated in the schist. If the gneiss and schist really form an alternating sequence in the stratigraphical succession as asserted by Huang, then there is no question as to the unity of the Tsinling System. If, however, the exposed zones of these rocks represent but the limbs of the closed and denuded folds, then Richthofen might still be justified in differentiating the schist from the older gneiss.

In their description of the distribution of the gneiss and schist, Chao and Huang state that the gneissic zone becomes narrower and less important towards the east of the range. This is essentially in agreement with the observations of

Willis and Blackwelder, who found no granitic zone along the northern foot of the range in longitude 108° 18′ E. But instead, they discovered a zone of green schist, mainly chloritic, succeeded by white quartzite and massive grey limestone probably of Sinian age. Still farther east, between longitudes 109° and 112°, Loczy reports an extensive belt of biotite-schist with gneisses and occasional marble penetrated by granitic and dioritic igneous masses, and broadly exposed on the southern side of the main range. The main range is also composed of a broad belt of schists and gneisses with igneous intrusions. Between these two belts of schist and gneiss stretches a narrow zone of quartzite, metamorphosed limestone and phyllite, probably of Sinian age. As is well remarked by Willis, these rocks agree in strike with those of the Funiushan, where Richthofen describes similar types of rocks accompanied by a large granite intrusion. It appears from the account of these authors that in this part of the Tsinling a granitoid gneiss is present besides the schists. The Tsinling Gneiss, as mentioned by Chao and Huang in the western part of the range, would therefore seem to reappear in the eastern part of the same range, but is apparently squeezed out in the middle part, namely, in the neighbourhood of longitude 108° 30′ E.

On petrographical grounds the schist can be correlated with the upper part of the Wutai, as is done by Richthofen and Willis. The gneiss must then be assigned either to the lower part of the Wutai or to the Archæan. Because of its intimate association with granite on the one hand and the occasional presence of marble on the other it is tentatively referred to the Archæan of the Inshan type.

The main axis of the Tsinling Range suffers a sharp bend to the east of the Funiushan. It is displaced to the south, forming the Tapeishan and Huaiyang mountains in north-eastern Hupeh and north-western Anhui. In these mountains T. Y. Yu found a zone of gneisses and schists invaded by granite forming the northern belt, which is succeeded southwards by folded Palæozoic strata. Further east, the mighty range gradually subsides, but the arcuate belt of crystalline rocks still persists towards the coast. In this arc, which is termed the Huaiyang Arc, Archæan rocks are undoubtedly involved.

Thus in the central and north-western parts of northern China we have probably an Archæan zone extending across the south-eastern part of the Nanshan Ranges. This zone merges into the Tsinling between longitudes 107° and 110° E. as it runs south-eastward. Further on it bends round towards the north-east and then north-north-east to form the axis of the Luliang and Taihang Ranges in the Shansi Plateau. Behind this broad sweep of an arc, and approximately in the mid-position of it, a nearly north-south zone of the Archæan is again exposed, forming the basal part of the Holanshan Range and its southern continuation. This bow-and-arrow structure is of fundamental importance in determining the tectonic characteristics of northern China.

An exposure of injection-gneiss, termed the Meijentou Gneiss, accompanied by the Kunglin Schist, occurs in the core of the Huangling anticline, in the Gorge district of the Yangtze. While it has been recognized that the coarse bands of the gneissic rock in this locality are largely due to the intrusive granite of pre-Sinian age, the more intense phase of metamorphism involving almost complete transformation of minerals had been brought about before the arrival of the granite. Hornblende becomes now and then so abundant in the gneiss and schist that the rock can almost be called epidiorite or amphibolite. The occasional presence of microscopic layers of more or less rounded clastic quartz discloses, however, its sedimentary origin. Although the Meijentou Gneiss and Kunglin Schist were formerly tentatively referred to the Wutai System, a careful comparison with the Sangkan Gneiss shows that, if the latter is to be considered as Archæan, the Meijentou Gneiss and Kunglin Schist must be also assigned to that group.

On the eastern side of the Lushan, central Yangtze, a rather fine-grained gneiss forms a narrow band along the eastern foot of the mountain. This gneiss is overlain by mica-schist and underlain by granite. In the granite masses bodies of gneiss also occur as if they had formed roof pendants before the granite became exposed. It is yet uncertain whether the gneiss belongs to the Archæan or is only an altered phase of the schist.

Extensive exposures of gneissic rocks have been mapped in the South-Eastern Uplands. They are particularly well exposed in the Shaling Range on the north-western border of Fukien and in the district between Kienou and Kienyang. Narrow belts of similar rocks run along the coast to the west of Amoy and then along the group of islands to the east of Amoy. The latter exposure probably extends to the islands off the coast of Fuchow.

In the Kienou and Kienyang districts the Archæan gneiss is often invaded by granite, also gneissoid in structure, and other igneous rocks. It is overlain by biotite-schist believed to be of Wutai age. In the Shaling Range, the Archæan gneiss is likewise penetrated by numerous igneous bodies and auriferous quartz veins. The character of the rock ranges from granitoid gneiss to gneissose pegmatite on the one hand, and to micaceous gneiss on the other. Granite abounds among the intrusions which often grade insensibly into the gneiss proper. Large bodies of porphyries frequently occur in the gneiss, but they are evidently of later age. In the neighbourhood of Amoy the Archæan gneiss is of granitic composition, with felspars, quartz and muscovite as its principal mineral constituents. Sometimes green hornblende forms dark bands or augen in the otherwise light-coloured rock. Basic intrusions and quartz veins also occur. Large granite bodies in the gneiss obviously arrived at a much later age.

Patches of gneiss of intricate structure are exposed on the southern side of the Sikiang in Kuangtung Province. They are associated with, and apparently overlain by, schists, quartzites and marbles. Hsu and Chiang, who mapped the area, regard the gneiss as Archæan.

Old gneisses and schists penetrated by granite are reported to occur in western Yunnan. They occupy an area extending from the Northern Shan States to the high watershed of the Kaolikongshan between the Salween and the Irrawaddy. Coggin Brown compares these rocks with the Taishan Complex of northern China.

A fairly extensive exposure of Archæan granitoid gneiss has been mapped by H. C. Tan and C. Y. Li in the eastern part of Sikang Province. The rock is often invaded by granite which resembles the gneiss in composition. For this reason, Tan and Li mention the difficulty of distinguishing the two in the field, and think that a part of the granite reported by Loczy from the same area probably belongs to the Archæan gneiss. Contrary to the usual expectation, this ancient rock is seldom penetrated by quartz veins. The source of the gold deposits, for which the Sikang area has been long famous, is not to be found, according to the same observers, in the Archæan, but largely in the coal-bearing formation of Jurassic age.

B. Wutai System

The Wutai System is widely developed in China, and particularly in northern China. It comprises a thick sequence of variably metamorphosed strata, often invaded by igneous masses, but their sedimentary origin is clearly recognizable. Richthofen first described this group of metamorphosed sediments in the Wutaishan, north-eastern Shansi. A more careful study from the stratigraphical point of view was later made by Willis and Blackwelder in the same area. These authors distinguished three series in the Wutai System. Named from the oldest, they are the Shitsui, the Nantai, and the Sitai Series. As observed in the Wutai area, the Shitsui Series is supposed to be unconformably underlain by the injection-gneiss belonging to the Archæan group. No clear-cut contact has, however, yet been observed. This series consists of mica-schists and gneisses, with a thick stratum of magnetite-bearing quartzite and some thin layers of the amphibolite in the upper part, and dark schists and ferruginous, arkose quartzites in the lower part. The total thickness of this series is estimated at 3,700 m.

The Shitsui Series is succeeded upward, according to the same observers, by the Nantai Series, consisting of siliceous marble, quartzites and schists, with a total thickness of probably more than 600 m. if the strata are folded in a closed syncline. From its position of occurrence and the general dip of the lower part of the Wutai System, there appears little doubt as to the higher stratigraphical position of the Nantai as a group of strata compared with the Shitsui Series. The actual contact between the two series has, however, never been observed.

The Sitai Series of Willis and Blackwelder is largely composed of chlorite-schist with quartzite and arkose conglomerate at the base resting on the Nantai rocks. After more extensive observations in the Wutaishan area, C. C. Sun accepts on the whole the general sequence of the Wutai System as established by Willis and Blackwelder, but refutes the hypothesis that the so-called Nantai Group forms a closed syncline. Sun considers the structure to be more simple than was assumed by members of the Carnegie Expedition, and proposes a fivefold division of the Wutai System, as quoted below in descending sequence.

5. The Kuantangkou Series (Nantai Group of Willis).
   Conglomerates, quartzites, phyllites, siliceous marble and jasper. Thickness about 600 m.

   Erosion Interval

4. Sitai Series.
   Chlorite-schists and quartzites, which constitute the main Wutai Range.

3. The Liutingszu Series.
   Conglomerates, green phyllites or schists, dark grey slates, crystalline limestones and quartzites. Thickness nearly 1,400 m. In the limestones Yang found certain peculiar bodies believed to be organic remains, and named *Gymnosolen sinensis* (*Fig.* 17.)*

   Erosion Interval

2. The Paiyunszu Series.
   White marbles, biotite- and chlorite-schists, quartzites and greenstones. Thickness about 2,540 m.

1. The Shitsui Series.
   Arkose and micaceous quartzites, gneisses and mica-schists. Thickness about 3,650 m.

* It is not improbable that the limestones containing the so-called *Gymnosolen* really belong to the Sinian System, being involved in the Wutai through structural complication.

In western Shansi, the Wutai formation is exposed in the western foothills of the Luliang Range, forming a narrow belt marked by the low ridge, Heikotaling. On the eastern side it lies in unconformable contact with the Archæan Complex of the Luliang, and is in places unconformably overlain by the Sinian System. The contact is characterized by an eroded and weathered surface of the Wutai rocks. In this part of the country the lower part of the Wutai System consists of highly metamorphosed clastic sediments, such as

FIG. 17. *Gymnosolen sinensis* Yang. × $\frac{3}{4}$. (After YANG.)

arkose quartzites, micaceous dark grey slates, and basic eruptive sheets, and has a thickness of about 850 m. The upper part begins with a thick mass of greenstone intercalated with banks of reddish quartzite. The greenstone is probably of volcanic origin, largely composed of hornblende. This is succeeded upward by a whitish-grey crystalline limestone, and then by a coarse-grained muscovite-garnet-schist which is partly rendered into a veined garnet-gneiss. The total thickness mounts to above 1,900 m.

Correlation on lithological grounds with the development in the Wutai area naturally favours the inference that the crystalline limestone (here about 350 m. thick) is equivalent to the Paiyunszu Series. The lower part of the sequence does not, however, correspond to, but is younger than, the Shitsui Series; for it has been pointed out by Sun that in the lower part of this sequence occur quartzite pebbles of the Wutai rocks, whereas the material forming the Shitsui Series is entirely derived from the Archæan. Analyses of the marbles of the Wutai System have almost invariably yielded a high percentage of magnesia. The Paiyunszu marble shows 25·82% of CaO and 22·07% of MgO on the average. This rock, probably Archæan, is widely distributed in north-eastern China. The Fangshan dolomite-marble occurring in the Fangshan district, west of Peking, has proved to be an excellent building material, and has been commonly used for the construction of the Imperial Palace in Peking. At times, the rock becomes so highly magnesian that it is a true magnesite. Such magnesite occurs in South Manchuria. The Niusintai variety (Wutai ?) in the Penchihu district is particularly suitable for metallurgical and refractory purposes. Brucite and even forsterite marbles are known in other parts of northern China. They belong largely to the Wutai System.

Along the Inshan Range, the Wutai System is represented by the Kuyang Formation, typically exposed to the north of Kuyanghsien. Other exposures have been found in Wutakou, north-west of Sarachi; Wanchiakou, north of Chasuchi; Wukungpa, north of Kueisui; and in a place midway between Taolinhsien and Santaoying. All these localities are situated in the Tachingshan Range. The formation usually consists of quartzite, marble and mica-schists with occasional phyllites. At Wutakou the marble rests unconformably upon the Sangkan Gneiss. On lithological grounds Sun correlates this formation with the Liutingszu Series of the Wutaishan area. The absence of injection-gneiss is said to be a feature which serves to distinguish the Wutai from the Archæan in isolated occurrences.

In northern Hopei and in South Manchuria, particularly in the area to the south-west of Mukden, extensive bedded iron deposits occur in between quartzite and mica-schist. In the lower part of the Wutai System, as developed in the type locality of the Wutaishan, ferruginous quartzite also occurs, so ferruginous that it is often magnetic. On this basis we might correlate the formation bearing the so-called Archæan iron-ores in north-eastern China with either the middle part of the Wutai or the Shitsui Series. A correlation with the latter series is the more feasible.

This characteristic ferruginous bed is, however, not always present in the Wutai formation. Our correlation of these ancient rocks must therefore largely, if not entirely, depend on their low stratigraphical position in a rather general sense, their lithological character, and the degree of metamorphism involving a certain type of mineral transformation. It will be realized at the outset that any correlation based on such criteria cannot, at its best, be anything but of a broad nature. Nearly all highly metamorphosed Pre-Cambrian sediments, with or without igneous intrusions, that have been found in China are referred to the Wutai System when the metamorphism has not gone so far as to have completely destroyed the bedded structure of the rocks.

In such a way the metamorphic series observed by Richthofen between Chefoo and Penglai in the north-eastern part of the Shantung Peninsula is guardedly compared by Willis with the development of the Wutai area. The succession begins with garnetiferous mica-schists, and is followed upward by crystalline limestone interbedded with schists and quartzites, recalling the Shitsui and Paiyunszu Series of the Wutai area. These strata are unconformably overlain by massive beds of quartz, quartz breccia and sandstones, probably of Sinian age.

Rocks comparable with those exposed in the Chefoo-Penglai section are developed further south in the Shantung Peninsula. According to H. S. Wang, the typical exposures occur at Kingkangkan, where the Wutai System unconformably overlies the Archæan Gneiss, and again at Huangyenti, where it underlies the Laiyang Formation of Cretaceous age. The whole sequence, well over 500 m. in thickness, largely consists of hornblende-mica-schist alternating with marble. It is not infrequently invaded by bodies and sheets of granite which, at one place, contains graphite. Citing the case of the Adirondacks, Wang argues that the graphite has probably originated from segregation. These Wutai rocks are probably co-extensive with the Archæan belt, reaching as far south as Haichow, north-eastern Kiangsu.

Apart from certain mica-schists, chlorite-schists and marbles occurring near Chihfeng and perhaps south of Lingsi, little of the Wutai System is developed in the Great Khingan Range. But the occurrence of numerous characteristic quartzite pebbles in the base of the Sinian, especially in the Hunglohsien area, and also in the Jurassic conglomerates developed in the range, led Teilhard to believe in a fairly extensive distribution of the Wutai System along the Khingan in former time, which had been swept off by erosion before the deposition of the Jurassic.

In the Gobi region C. Berkey and F. Morris frequently encountered a group of rather highly metamorphosed rocks such as slates, phyllites, schists, limestones and conglomerates overlain by the greywacke series. Because of the fact that these rocks are clearly altered sediments and can be easily distinguished from the rocks of the Taishan Complex type, and because of the comparability of the greywacke series overlying it with the Sinian sediments, Berkey and Morris naturally correlate this " ancient crystalline Complex " with the Wutai System. On account of the presence of conglomerates in this complex they further suggest that these rocks consist, at least, of two series. In the Artsa Bogdo Range of the Altai Mountains chlorite-schists occur, and to the north of Pangkiang mica-schists and phyllites are associated with limestones. Lithologically, such rocks are not unlike those of the Sitai and Liutingszu Series. Among this group they also found a vast series of greenstones and chloritic phyllites in the mountains east of Ardyn Obo. These rocks, the same authors suggest, might be of volcanic origin, reminding us of the development in western Shansi.

Owing to advanced metamorphism affecting the Lower Palæozoic strata in the Nanshan Ranges, it has not been possible to separate any part of the Nanshan Series from the Lower Palæozoic, which also consists of schists, slates, quartzites and limestones. The fossiliferous limestone only occurs, however, in the upper part of the series, which is estimated at no less than 2,000 m. in thickness in the south-eastern prolongation of the Nanshan Ranges. South-east of Lanchou, a broad zone of true Wutai rocks appears to extend to the south-east, covering the districts of Lungsi, Tienshui, Chingshui and Paochih. In the last-named district, the zone merges into the Tsinling.

From various records of observations made across the Tsinling Range we can establish the fact that a rather broad zone of schists, quartzites and crystalline limestones of the Wutai System stretches out for an enormous distance, almost west and east, in the northern part of that range, closely following the Archæan. This zone abruptly terminates at the eastern end of the Funiushan with an isolated belt exposed to the south of Mihsien, but reappears further south, forming the Wutangshan in north-western Hupeh, the Tapeishan on the north-eastern border of that province, and the Huaiyangshan in western Anhui. Eastward, the mountains rapidly subside, but the ancient metamorphic zone still persists to form the Huaiyang arc, being here and there covered by young sediments. Further east, greenish-grey schists appear once again in the neighbourhood of Chuhsien (about lat. 32° 30′ N., long. 119° 20′ E.), forming low hills. Then these ancient rocks dive under the recent deposits towards the coast.

In southern China, south of the Tsinling Range, exposures of the Wutai rocks are comparatively few. When they occur, they are only exposed in relatively restricted areas or in the basal part of highly dislocated mountain blocks. Such is the exposure of the Lushan Schist in the south-eastern part of the Lushan (about lat. 29° 30′ N., long. 116° E.). The lower part of this schist consists of a rather uniform garnetiferous mica-schist, and is succeeded upwards by hornblende-schist and then schistose sandstones and clayey phyllites, aggregating more than 600 m. in thickness. This series of metamorphosed rocks is underlain by still more highly metamorphosed gneiss, which is in direct contact with granite, and overlain by slates and quartzose grit of Sinian age.

To the south-east of Lingchuanhsien, south-eastern Kiangsi, a group of mica- and chlorite-schists, intercalated with graphite-bearing gneiss, attains a fairly wide distribution, occupying a belt of country apparently running north-east. These rocks often contain igneous intrusions and quartz veins. To the north of Lingchuan mica- and chlorite-schists alternate with a massive formation of phyllites. H. C. Tan and S. W. Wang regard these rocks as of "Algonkian" or Sinian age, presumably on account of their structural complexity and their lithological character. Similar rocks occur in north-western Fukien, and are particularly notable in the Kienou, Kienyang and Nanping districts, where they are associated with the Archæan. In the Nanping and Tsaotuh districts, this formation contains marble, and is often penetrated by small igneous bodies and quartz veins which are sometimes copper-bearing.

More extensive are the exposures of indisputable Wutai rocks in Kuangtung to the south of the Nanling Range, forming approximately an east-west zone in between lat. 23° 15′ and 23° 30′ N. According to T. C. Lee, who mapped the area and described the formation, the whole metamorphic sequence can be divided into an upper and a lower series. The upper series is far better developed, and consists of an alternation of schists, quartzites, gneisses, schistose sandstones and conglomerates, phyllites and slaty rocks invaded, in numerous places, by granitic dykes and even more often by diorite. The lower series consists of coarse-grained gneisses with granitoid structure. More careful investigation may eventually show that this lower series should be properly assigned to the Archæan. These metamorphic rocks are overlain by a series of altered sandstones and shales which, on account of their lithological character, are correlated by Lee with the Middle Devonian.

The same metamorphic zone extends into the Sikiang

Valley, covering many districts on the southern side of that river. There, among the usual schists, gneisses and quartzites, marbles, in addition, are present. They are penetrated by granite with fluidal structure, and are themselves often contorted. Further west, the same zone is slightly deflected to the south past the Yunghsien district in Kuangsi, and then enters into the Linshan district to form the lofty Tientsangshan. In this western extension of the zone the dominant rock is augen-gneiss with the usual quartz and felspars and abundant black mica. These rocks are reported to be overlain by metamorphosed Lower Palæozoic strata of the Lungshan Series.

In western Yunnan a complex group of phyllites, quartzites and mica-schists, together with highly metamorphosed limestone, forms a broad zone, the Kaolikongshan, between the Irrawaddy and Salween, and a narrower zone along the Lantsangkiang Valley. In the western zone they are discordantly underlain by the Archæan gneisses and schists and overlain by Palæozoic strata. These rocks were first noticed by Coggin Brown, who gave them the name Kaoliang Series, and more recently by W. Credner, who also found these rocks in the core of the Tientsangshan on the western side of Lake Tali, and in a few other places of limited extent. In the high ranges to the west of the Red River, such as the Ailaoshan and Wuliangshan, similar gneisses and schists form long belts according to H. M. Meng.

Some of these metamorphosed rocks probably extend into the province of Sikang on the Tibetan border. The information so far available does not, however, warrant any positive statement.

The Lulianian Revolution

Exposures of the Wutai rocks in China are scattered, as we have seen, over a vast territory, extending from Mongolia to Kuangtung and from the high mountains in northwestern China to the South-Eastern Uplands. Wherever these rocks are exposed, we find, without exception, strata that have undergone intense metamorphism, indicating that they had been subjected either to strong thermal influence, or dynamic effects, or both.

Large igneous masses are not always associated with these rocks, but the intensity of metamorphism that they exhibit is all the same. Dynamic metamorphism must have therefore played an important part in bringing about the result.

It may be argued that this universal metamorphism of the Wutai rocks is not necessarily due to a simultaneous display of the metamorphic processes, but rather to our own classification. If we choose to classify all the highly metamorphosed strata apparently low in the stratigraphical column, as the Wutai, then that universal metamorphism would have no objective meaning; for in such a scheme of classification relatively unaltered rocks of true Wutai age

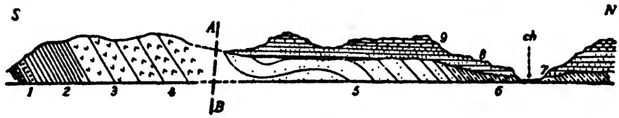

FIG. 18. Section along the Chinglokolan road, between Hsimafangchen and Chinerhying (N.W. Shansi), showing the unconformity between the Sinian and the Wutai formations. (After TEILHARD.)

1. Arkoses, siliceous slates and quartz-conglomerate. 2. Nodular or spotted slates. 3. Altered (epidotized, uralitized and albitized) andesite. 4. Amphibolitic rocks. 5. Thick hard quartzite. 6. White and pink mica-schists. 7. Basal conglomerate. 8. Quartzitic sandstone. 9. Cambro-Ordovician limestone. Between 8 and 9, shales are probably present, but were not actually observed. 1-6, Wutai cycle. 7-9, Palæozoic cycle. Approximate length of the section, 10 kilometres. *ch.*, Chinerhying. *AB*, fault?

may be excluded from that system, and highly altered rocks of post-Wutai age might be included in it.

This argument, rather superficial as it is, requires a thorough consideration so as to expel every element of doubt. It has to be admitted that in the absence of fossil evidence we are deprived of a rigorous means to effect stratigraphical correlation. But in dealing with the Wutai rocks as a group we are not so much concerned with the correlation of the subdivisions of the system, but rather with the correlation of the system as a whole with others. The Cambrian and post-Cambrian formations need not come into the question. The only possible confusion may arise from the assumption that locally metamorphosed Pre-Cambrian strata younger than the Wutai may have been included in the Wutai, and relatively unaltered Wutai may have been assigned to a later Pre-Cambrian age. That such an assumption cannot be true will be rendered self-evident when we come to deal with the Sinian System. This latter system also belongs to the Pre-Cambrian, but apart from metamorphism it has lithological characteristics of its own which are not found in the Wutai. Moreover, unconformable contact between the two systems has been observed in many localities all over northern China. The rocks below the plane of unconformity are intensely metamorphosed, but the sediments above it, namely, the Sinian System, are hardly altered. These circumstances are obvious enough to show that there is no gradational change in the degree of metamorphism in the two systems as might be expected if the metamorphism is simply due to the increase of depth.

Because of the fact that this far-reaching movement is particularly well shown by the pre-Sinian unconformity on the western side of the Luliang Range, it might be appropriately named the Lulianian Revolution. In point of time, this movement seems to correspond to the main phase of the Laurentide Revolution in North America, and the pre-Torridonian movement of north-western Europe.

C. Sinian System

As already remarked, the name Sinian Formation was first used by Richthofen to denote a mighty sequence of rocks in northern China that overlies the Wutai Formation and underlies the so-called Kohlenkalk. Richthofen divided his Sinian into two parts. The lower part essentially belongs to the Pre-Cambrian, while the upper part belongs to the Lower Palæozoic. After separating the Huto or Nankou System of Pre-Cambrian age from the Sinian in Richthofen's sense, Bailey Willis and Eliot Blackwelder restricted the Sinian to the Cambro-Ordovician formations. Since the time of the Carnegie Expedition many more stratigraphical units have been recognized in the Sinian System of Willis. For this and other reasons A. W. Grabau discusses at some length the propriety of limiting Richthofen's term Sinian to the lower part of Richthofen's Sinian Formation, equivalent to the Huto System of Willis. The Sinian System of Willis is consequently resolved into a number of formations, each having its local significance. Grabau's emendation of Richthofen's original term has now become widely accepted in Chinese geology.

In view of the fact that the Sinian strata play an important part in the sedimentary record of China, more especially of northern China, and that the correlation of these strata by their questionable organic remains can be effected with some precision, we can deal with these rocks in a more positive manner. Even if the alleged organic remains prove to be inorganic, the mighty sequence of the rock-material will serve as ample evidence that conditions on our earth essentially similar to what we perceive to-day prevailed long before Cambrian time.

Let us now examine a classical section of the Sinian rocks in the Nankou Pass, north-west of Peking, first observed and described by Richthofen and later studied by the graduates of the Peking University. In the lower part of the sequence, massive, white quartzite, intercalated with black slate and aggregating a thickness of some 200 m., unconformably overlies gneisses and schists of the Wutai formation. Higher up in the sequence, massive, siliceous limestone with intercalated quartzites, often false-bedded, forms a well-bedded series.

The siliceous limestone is often exceedingly hard and contains lenticular bands and nodules of flint. The total thickness of this siliceous limestone is estimated at 1,000 m. or more. Peculiar, cylindrical, spherical and conical bodies occur in this limestone at several horizons. They generally show a laminated structure. The laminæ are concentric and extraordinarily fine in most cases, but sometimes rather coarse. In some cases, they are not unlike the so-called paramoudra in the Norfolk Chalk. The size of the cylinders varies from 2 to 20 cm. in diameter, and up to 60 cm. in length. Other types also vary considerably in size. In one place where the limestone is weathered away along its bedding plane, these cylindrical bodies stand on the weathered surface like a host of studs. After the fashion of most American authors, these bodies are considered as fossilized algæ, named *Collenia* or *Cryptozoon*. Under a high-powered microscope nothing but a mosaic of calcite crystals is seen. So far no trace of organic cells has been detected.

The Nankou section is far from being complete in showing the Sinian sequence of strata. Standard sections of

FIG. 19. *Collenia cylindrica* GR. (Reduced.)

these rocks have been carefully studied by C. S. Kao and others in the Chihsien and Hsininghsien districts in the borderland between Jehol and northern Hopei. In the Malanyu anticline Kao and his colleagues found Archæan gneiss forming the core of the anticline. On the southern side of the Archæan core the Sinian strata are developed *par excellence*. The lower division of the sequence consists of massive quartzites and shales, with indefinite layers of conglomerate near the base and isolated patches of andesitic lava at the top, and totals 1,500 m. in thickness. The upper part of the sequence mainly consists of limestones in which shales occur at three different intervals. The lowest limestone in this upper division, named the Kaoyuchuang Limestone, contains some quartzites, slates and shales in its basal part, but they soon give way to a thin-bedded siliceous limestone with some intercalated shales or slates. Higher up, the limestone becomes massive. In the uppermost part flints appear in the limestone. Strange bodies attributed to *Collenia* occur at two horizons: one near the base and the other at the top. The total thickness of this limestone is estimated at from 1,050 to 1,300 m.

Overlying the Kaoyuchuang Limestone is the Yangchuang Formation, a white-spotted, blood-red mudstone with milky white bands. The white bands, usually a few centimetres thick, occur at intervals of some 50 to 70 cm. The material of which the mudstones is composed is said to be exceedingly fine and homogeneous. It attains a thickness of 410 m.

More limestone with laminated flints follows, which, after piling up a thickness of over 1,500 m., is succeeded by dark coloured shales, 200 m. thick. Then comes the Tiehling Limestone, a rather pure limestone intercalated with some shales in its basal part. *Collenia* abounds in this limestone. A tubulate type of such bodies is particularly abundant in the upper part of the limestone. The total thickness of the Tiehling Limestone is estimated at 350 m.

The topmost formation of the Sinian in this section is the Hsiamaling Shale, a carbonaceous shale containing hæmatite-bearing sandstones at the base and some false-bedded quartzite near the top, and having a total thickness of 360 m. This shale is apparently conformably overlain by another limestone in which occur small trilobites, apparently belonging to *Redlichia,* of Lower Cambrian age. Here shines, for the first time, the light of life rather advanced in the organic scale. Thus the upper division of the Sinian in this section amounts to no less than 3,870 m. in thickness. A similar sequence appears on the borderland of the Kaiping Basin. Nowhere else in China, and probably in no other place in the Eurasian continent, are the Sinian strata, or strata comparable with the Sinian in age, so well developed as in these localities.

Traced eastward, limestones and quartzites of similar description are widespread in South Manchuria. They are particularly well-developed along the front of the Great Khingan. The familiar bodies of *Collenia* or *Cryptozoon* again occur in two different horizons. In the quartzite another type of the supposed algæ, named *Manchuriophycus*, is reported to occur. These branching, tubular bodies, looking like worm burrows, are said to possess numerous "microscopic filaments." Indeed, they may be nothing but worm burrows that have been honoured with a mystifying name.

West of the locality where Kao and his collaborators described the standard section, the Sinian rocks discontinuously extend along the northern border of Hopei, and become split into two branches in the north-western part of that province. The northern branch stretches into the Hsuanhua district, south-east of Kalgan, where the limestone is partly replaced by botryoidal iron-ores. Thence westward, it is exposed on the northern side of the Sangkan Valley, forming gentle rolling hills with the well-bedded limestone lying almost flat. Further west, only the lower part of the Sinian System is preserved in the Pailungshan and Huhsingshan, north of Anpeihsien and Hsiyingtze, 30 km. north-west of Tumulu. Here the basal part of the system consists of a quartzitic slate followed by a cliff-forming siliceous limestone, with a total thickness of about 130 m. The beds are nearly horizontal, and rest unconformably upon a deeply weathered Archæan complex. The south-western branch stretches across Nankou and the Western Hills of Peking, where they are overlain by Cambrian and later sediments. In these places the lower part of the Sinian seems to have thinned down or even at times completely to have disappeared.

Belts and patches of Sinian rocks are found all along the Luliang Range and its north-eastern continuation. On the south-eastern side of the Wutaishan, Willis and Blackwelder map a Toutsun Slate, a Huto Limestone and a

Tayang Limestone. These strata undoubtedly belong to the Sinian. By comparing them with Kao's section the inference that the Huto overlies the Toutsun is entirely borne out. As estimated by Willis, the Toutsun Slate is probably 1,000-1,800 m. thick, and the Huto Limestone 900 m. or more. The Tayang probably represents a facies of the Huto.

Further south-west, only the lower division of the Sinian is developed in the Luliang Range. In the western flank of that range the Sinian consists of conglomerates, sandstones, shales and marls, with a thick bed of boulders and sheets of basic lava and tuff in its upper part. In the south-eastern slope of the south-western part of the same range, silicified Sinian limestone is sometimes exposed immediately below the Cambro-Ordovician limestone in the northern section, but is entirely wanting in the extreme south-western part of the range where the Cambrian shale rests immediately upon the Archæan.

On the south-eastern side of the Lower Fenho Valley, the whole range of the Fenghuangshan is formed by a thick series of Sinian sandstones, shales and a few limestones in the upper part, dipping gently to the south-east and lying unconformably upon the Archæan. The upper part of this series apparently merges into the Cambrian. In the Hoshan Range, on the eastern side of the Fenho Valley, much farther north of the Fenghuangshan, the Sinian appears to be absent. A quartzitic sandstone questionably of Cambrian age rests immediately upon the Archæan.

Along the Taihang Range, south of the Hutoho, Sinian strata are exposed from place to place in the axial part of the Taihang anticline. They occupy a limited area in the north-western corner of the Chinghsing coalfield and form low hills near Hueiluhsien along the Chengtai Railway. In the Chingsing area, the lower part of the Sinian rests unconformably upon the Wutai schists, quartzites and marble, and is composed of quartzites and black shale which contains a bed of iron, including ore comparable with that of the Hsuanhua and Lungkwan districts in north-western Hopei, but attaining only a thickness of about 7 m. The upper part consists of a flinty silicified limestone varying from a few metres to 20 m. in thickness. In the Hueilu district, the silicified limestone thickens to about 120 m., but the quartzite in the lower part is reduced to about 25 m. Various forms of the so-called *Collenia* occur in this part of the system.

In the Lingcheng coalfield, south of Hueilu, the Sinian is entirely represented by quartzites. Still further south in the Wuan, Shehsien and Linghsien districts, northern Honan, the Sinian quartzite with basal layers of red conglomerate and green sandy shales unconformably overlies the Archæan. The quartzite is particularly well exposed along the Changho. In this southern part of the Taihang Range the Sinian is not only free from calcareous sediment, but the quartzite of which it is largely composed also shows a tendency to thin out towards the south. False-bedding, sun-cracks, and ripple marks are frequently found in the quartzite.

Similar quartzites occur to the south of Mihsien, northern Honan, unconformably overlying the Wutai schists and marble, and forming a belt running east by south in association with the latter formation. This belt virtually runs along the northern border of the Tsinling zone. The quartzites are therefore dynamically metamorphosed, often showing secondary growth of quartz surrounding the rounded quartz grains.

An interesting locality showing the widespread nature of vulcanicity in Sinian times is the one in the Lushan district, on the northern side of the Funiushan, central Honan. Here, the " Archæan " is overlain by amygdaloidal lava and pyroclastic rocks, which are in turn succeeded by quartzitic sandstones. The lava sheets are sometimes intercalated in the sandstones.

Apart from the peculiar quartz-breccia of questionable Sinian age observed by Richthofen between Chefoo and Penglai in eastern Shantung, no true Sinian strata have ever been found in the vast area of the Shantung massif, except on its southern border extending discontinuously from the Yencheng and Pihsien districts. The dominant rock is a fine-grained quartzite occasionally intercalated with layers of red shale and irregular masses of hæmatite. Its association with the Wutai on the one hand and with the Cambrian on the other, together with the occurrence of iron-ores, makes it fairly certain that the formation belongs to the Sinian.

Turning to the north-west, we find a few scattered masses of the Sinian along the Inshan Range, being virtually the western continuation of the Nankou Limestone already mentioned. Instead of Nankou Limestone, Sun applies, however, the local term, Shihnakan Limestone, since it is well developed at the western end of the Sheitenula, to the north of the village of Shihnakan. In this part of the range, the Sinian limestone is generally well-bedded, dark grey in colour and more or less earthy in composition. Flint abounds in one place, but is rare in another. It is unconformably underlain by the Sangkan Gneiss and overlain by the Permian. Dynamic metamorphism has partly affected the limestone.

Towards the east, a similar limestone occurs in the neighbourhood of Chiutsaikou, north-east of the Wuchuan district. There the limestone, with a few characteristic flints, unconformably overlies the Sangkan Gneiss. Towards the west, a siliceous limestone believed to be of Sinian age is frequently exposed along the foot of a long ridge which stretches from the west of Uniusu to the neighbourhood of Etsin Gol along the latitude of about 42° N.

North of the Inshan Range, a series of siliceous and flinty limestones, interbedded with slates and black shales, occurs in the Beiyin Obo district (about 42° 15′ N. and 110° 45′ E.). With these rocks are associated iron-ores under conditions similar to those in which the Sinian iron-ore occurs in the Hsuanhua district, south-east of Kalgan. The rock-types are also comparable with the familiar Sinian strata.

A mighty series of greywacke with interbedded shales and slates, termed the Khangai Series, is extensively distributed in Mongolia, especially in the Khangai and Kentai Mountains. These rocks are frequently " undercut " by the great Mongolian bathylith. They have yielded no fossils except doubtful worm burrows and obscure markings. The unfossiliferous nature of these rocks, their less altered state as compared with the crystalline complex, and their occasional association with calcareous lenses which bear the enigmatic organic structures so familiar in the Sinian limestones, are among the more important facts that led Berkey and Morris to compare them with the Sinian development further south.

Using the term Khangai Slate in a much broader sense (probably including Permian limestone), Teilhard has traced the formation to the northern part of the Nanshan Ranges. In the northern slope of the Nanshan, Loczy distinguished a Nanshan Sandstone, a greenish-grey sandstone intercalated with clayey slates, barren of fossils except for doubtful fucoidal impressions. In places this sandstone is conformably stratified with rather thick-bedded, siliceous and dolomitic limestones. Analyses of the Sinian limestone occurring in north-eastern China often yield an appreciable amount of magnesia. The Nanshan Sandstone of Loczy, together with its associated dolomitic and siliceous limestones in the Nanshan Range, may therefore be assigned to the Sinian, if it proves to be distinct from the Nanshan Series of Hsieh, or to be equivalent only to the lower part of the latter series.

In the Kuruktagh Norin found a thick sequence, probably not less than 1,000 m., of shales and tillite interbedded with thin layers of limestones. Careful investigation by Norin himself has shown that this tillite is of Sinian age and not of Permo-Carboniferous age as it was originally reported to be.

Sinian limestone appears to attain a considerable development in the Alashan Range on the western side of Upper Huangho. No detailed information as to the stratigraphy of this area is as yet available.

In the main range of the western Tsinling no indisputable Sinian rocks have yet been recognized. Huang discusses, however, a series of unfossiliferous dark green slates and well-bedded quartzite under the term Tsoshui

Series. According to Chao and Huang, these rocks form an extensive belt in the axial part of the Tsinling, stretching at least between longitudes 104° and 110° E. On its northern side it is in direct contact with the Wutai Formation, and on its southern side rocks ranging in age from Silurian upwards appear in succession. Huang correlates these rocks with the Heishui Series of Willis, but differs from the last named author in holding the view that a part of that series might probably represent the Sinian.

On the southern side of the eastern part of the Tsinling Sinian strata are well-developed. Between Shangchi and Sichuan, southern Honan, a thick and well-bedded dark limestone of Sinian age forms the high mountains. After disappearing for a time in the Nanyang-Hsiangyang Gap, this belt of hardly metamorphosed Sinian strata continues to extend to the south-east on the southern side of the Tapeishan, covering parts of Hsiangyang, Suihsien, Kinshan and Anlu. In this part of the country the Sinian belt attains a width of more than 50 km. Towards the south-east it narrows down, forming foothills along the front of the Huaiyang arc.

In this arcuate belt, the Sinian consists of two parts. The lower part is composed of alternating beds of micaceous phyllite and silvery grey, talcose sandstone. The upper part begins with an alternation of slaty shale and flinty limestone, followed by purer limestones with numerous beds of flint. West of Yinshan the upper part everywhere rests on the lower part; but in south-eastern Hupeh, the upper part of the Sinian comes into direct contact with the Wutai, indicating the transgression of the upper Sinian. The thickness of the whole series is estimated at more than 1,000 m., of which more than half is limestone belonging to the upper part.

Further south of the Tsinling zone, the Sinian extends into the south-west on the one hand and into the south-east on the other. The south-western branch appears again to be divided into two areas, with the Kweichow Plateau lying between. These two areas become conjoint in the gorges of the Yangtze. Here, unquestionable Sinian strata flank the Huangling anticline. In the eastern limb of that anticline these rocks are particularly well exposed. The whole sequence begins with a quartzose sandstone followed by the Nantou Tillite, and then a series of black slates and slaty limestones which apparently merge into a massive, white limestone, named the Tongyin Limestone. In the basal part of the Tongyin Limestone the questionable algal remains occur abundantly in places. These laminated, cylindrical, and conical bodies often stand in a vertical position. They are sometimes attached to small rhomboidal blocks of a slaty limestone probably derived from the lower part of the Sinian. It was suspected that they might have been stalactitic deposits, but the absence of fissures or any other kind of regular surface, in the place where they occur, renders it extremely unlikely that such is the case. When broken through, the laminated rods never show any central structural element that might have served as a nucleus for starting concretion. The laminated cones are in rare cases penetrated by more or less irregularly curved tubes about 5 to 6 mm. in external diameter, a little over 1 mm. in thickness, and up to 8 or 10 cm. in length. Considering the circumstances under which these tubes occur it is difficult to entertain any doubt as to their organic origin. They may represent some simple annelid.

The whole sequence of the Sinian in this locality amounts to 800 m. It is unconformably underlain by the Huangling Granite, probably of Wutai age, and overlain by Lower Cambrian shale with characteristic *Redlichia*. From this stratigraphical determination it becomes evident that the Nantou Tillite, originally supposed to be of early Cambrian age, lies, in fact, rather low in the Sinian sequence. Nor is this tillite a local development. In the Hsinshan district, some 50 km. north-west of Nantou and along the eastern border of the Kweichow Plateau, the same glacial deposit has been recently found.

Limestones of Sinian age have been reported to occur on the south-eastern border of the Red Basin of Szechuan. They are again observed in the Omeishan district in the south-western part of the same basin. In this locality the

Sinian limestone is estimated at 800 m. in thickness, and is underlain by a pre-Sinian granite. No glacial deposit comparable with the Nantou Tillite has, however, been found. This is well within our expectation if the deeper part of the Sinian trough ran across this part of the country.

Sinian strata are probably extensively developed on the eastern border of the Kweichow Plateau and western Hunan. A series, more than 1,000 m. thick, consisting of green sandstone, conglomerate, white quartz sandstone and shales, has been found in south-western Hunan extending across the eastern part of the middle Nanling. The lower part of this Nanling series may belong to the Sinian. Nothing, however, is definitely known showing the characteristics of the Sinian System such as have been established in other parts of the country.

The south-eastern Sinian basin lies in Kiangsi and southern Anhui. In this area the Sinian development is typically exposed in the Lushan (about 29° 30′-37′ N., 116° E.), where the rocks are slates, shales, hard grits, porous ashy sandstones, and micaceous sandstones, with a thoroughly silicified limestone, the Matsu Limestone of Richthofen, capping the series. This sequence is overlain by *Redlichia*-bearing shale. Its Sinian age is thus unquestioned. The complete series is of a considerable thickness. The grit alone is estimated as 800 m. Richthofen erroneously considered this grit to be Devonian.

In the north-western part of Kiangsi and in the high mountains forming the boundary between Kiangsi and Hupeh is developed a sequence of greenish calcareous shales sometimes intercalated with thin-bedded sandstones, carbonaceous layers, conglomerates, white quartz sandstones and bedded chert or flint. Some 1,700 m. thick, it is questionably assigned, at least in part, to the Sinian by C. C. Wang. From the neighbouring region Y. Y. Lee reports a Shuangtsiao Series consisting of sandstones and shales, some of which are also of greenish colour. The two series are apparently identical. Lee is, however, of the opinion that this highly disturbed series of great thickness is unconformably overlain by clastic sediments which he considers to be Cambrian.

Further down along the Yangtze Valley a thick sequence of calcareous, argillaceous and arenaceous strata is developed below the fossiliferous Lower Ordovician. They are widely distributed in the Shihtih, Taiping and Hiuning districts, south-eastern Anhui, on the border of the South-Eastern Uplands. The upper part of this sequence is composed of an alternation of argillaceous limestones and shales, and greenish and purple sandstones, shales with purple sandstone and conglomerate forming the base. This series, some 600 m. thick, probably belongs to the Cambrian. The lower part consists of a pale green, lumpy calcareous shale with interbedded quartzite, carbonaceous shales and bands of hornstone in the higher horizons and a greenish arenaceous clay-slate in the lower, having a total thickness of more than 800 m. This lower part of the sequence, probably partly, if not entirely, belongs to the Sinian. In these questionable Sinian beds Y. Y. Lee found a rather persistent stratum, some 8 or 10 m. thick, of a shaly mudstone containing pebbles of distant origin. It remains to be shown whether this peculiar deposit bears relationship to the Nantou Tillite.

If we now piece together the scattered observations throughout the country, some definite conclusion can be drawn as to the distribution of the transgressive Sinian water in the latter part of the Sinian period. A deep trough ran from South Manchuria to western Hopei and north-eastern Shansi. This trough continued to the south-west along the Luliang Range, but became shallower towards the south. Along the Inshan zone between Mongolia and northern China another fairly deep trough ran east-west, sending a branch to the south along the Alashan Range on the western side of the Upper Huangho. The third trough was located on the southern side of the eastern Tsinling, following the front of the Tapeishan and Huaiyang arc, apparently disappearing both to the west and to the east. The fourth trough started from western Hupeh, extending to the south-west as far as the south-western part of the Red Basin of Szechuan. This trough was possibly accompanied by one passing along the eastern front of the Kweichow Plateau and stretching across the Nanling Range. The fifth trough was located on the north-western side of the South-Eastern Uplands.

Apart from the Inshan and Tsinling zones, which later gave rise to the east-west mountain ranges, all the other troughs have a general north-east trend. They are in fact the forerunners of the Palæocathaysian geosyncline. We shall see in the following chapter that these local troughs were nearly all flooded by the Lower Cambrian sea which drowned the adjacent land areas and formed a single sheet of epicontinental water.

Correlation

From this brief account of the late Pre-Cambrian rocks in China certain broad features emerge. Unlike the conditions in north-western Europe, with the exception perhaps of Fenno-Scania, we are here brought to face a formidable sequence of sedimentary strata marked by notable stratigraphical breaks. In a rough parallelism we may compare the Sinian with the Algonkian of North America. A number of outstanding facts favours this comparison. They are both of relatively undisturbed sediments immediately underlying the Cambrian. In the Belt Terrain, peculiar laminated bodies referred to *Collenia* occur as they do in the upper part of the Sinian limestone. The Animikian iron-ore may be compared with the Sinian iron-ore in the Hsuanhua district, which is likewise of considerable economic importance. Above all, the Huronian Tillite affords a significant landmark. As we know now, the Nantou Tillite is by no means a local formation; it signifies a wide-spread cold climate in the early Sinian times over eastern Asia. So does the Huronian Tillite over the northern part of North America. Similar evidence is available in other parts of the world, *e.g.*, the tillite in the Sparagmite Series of Norway.

This correlation agrees admirably with the geodynamic correlation; for the Sinian is separated from the underlying Wutai by an unconformity of flagrant and extensive nature, and so is the Huronian from the Sudburian and Laurentian. The Lulianian Revolution can therefore be paralleled with the Laurentide Revolution. Following this parallelism we may compare the Wutai with the Keewatin Series. The Lewisian Gneiss and the Torridonian Sandstone that we see in Scotland represent, therefore, but portions of a prolonged geological history of the earth.

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CHAPTER III

MARINE TRANSGRESSIONS AND EPOCHS OF TECTONIC MOVEMENT

It is fairly well established that in the latter part of Sinian times eastern Asia was broadly folded along the continental border with a broad and long trough, the Palæocathaysian geosyncline, on the inland side, and a raised strip of land-mass, Palæocathaysia, bordering the Pacific. This geanticline and its complementary geosyncline ran almost parallel with the margin of the continent, bearing a striking similarity to the Appalachian geosyncline and Appalachia in the eastern part of the North American continent.

At the same time, at least one, probably two, land barriers extended into, but not quite completely across, the geosyncline from east to west. One of these east-west zones was apparently located in the position of the present Tsinling Range (about lat. 33°-34° N.); the other, though less sharply defined, probably occupied the area in the eastern part of the present Nanling Range (about lat. 25°-26° N.) and to the south of it.

In the sequel we shall deal with the major groups of deposits formed in the several basins which came into existence after each episode of earth movement. In this brief account of geological changes we shall pay more attention to the succession and nature of the sediments and the characteristic fossils that they contain, and to the chronology of the more important tectonic movements. Such terms as Caledonian, Hercynian or Variscan, Yenshanian and the like will be used in this and the following chapters only in the temporal sense. The trend of the tectonic features brought about by each of these movements will be separately dealt with in connection with our tectonic discussion.

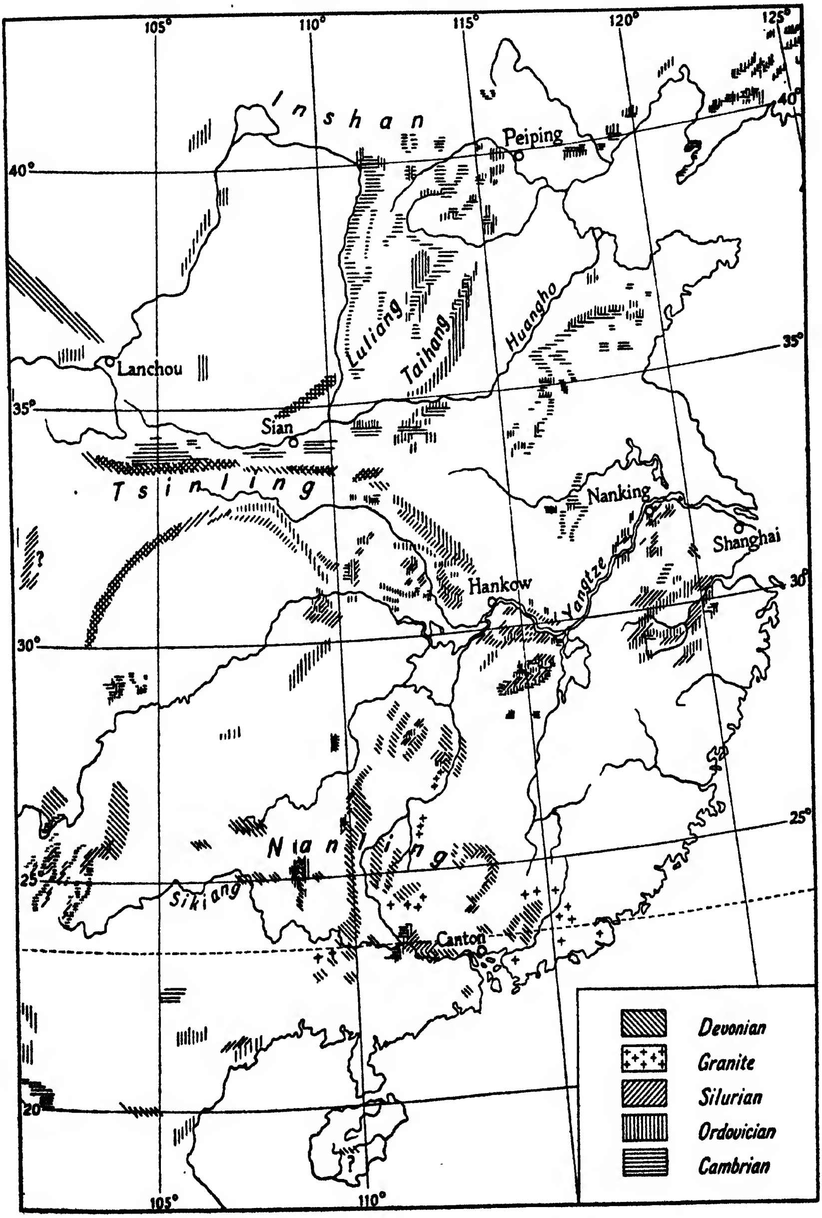

FIG. 20. Map showing the distribution of Lower Palæozoic and Devonian deposits in China.

Cambrian Transgressions

In early Cambrian times the Palæocathaysian geosyncline continually subsided with a consequent widespread marine transgression. Peneplaned land areas in or near the trough were drowned. Nowhere, however, have we found any evidence of folding accompanying this readjustment between land and sea. But the phenomenon of transgression is almost universal. The Peninsula of Shantung, which stood above the Sinian water, was at least partially submerged under the transgressive Cambrian sea. It is in the western part of Shantung that the Carnegie Expedition distinguished, with the collaboration of Walcott, several series, each with a characteristic fauna, in the Cambrian formation. The classical sections described by Willis and Blackwelder

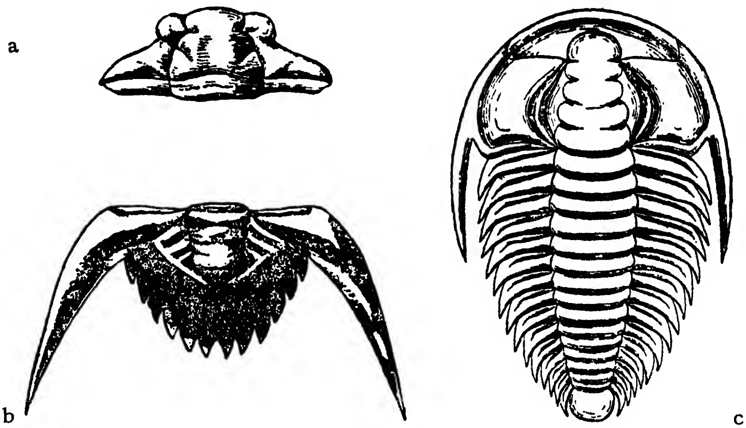

Fig. 21.
a & b. *Drepanura premesnili* Bergeron. a. cranidium, b. pygidium. Middle Cambrian. × 1 approx.
c. *Redlichia chinensis* Walcott. Lower Cambrian. × ⅗.
(From Grabau's "Stratigraphy of China.")

have been referred to ever since as a standard development for the Cambrian in northern China.

The lower part of the Cambrian known in north-eastern China generally consists of red and sometimes buff or brown and occasionally greenish shales in which occur lenticular layers of limestone. In some places this shale is divided into two parts by a thick limestone. In other places red sandstones and conglomerates appear at the base. The

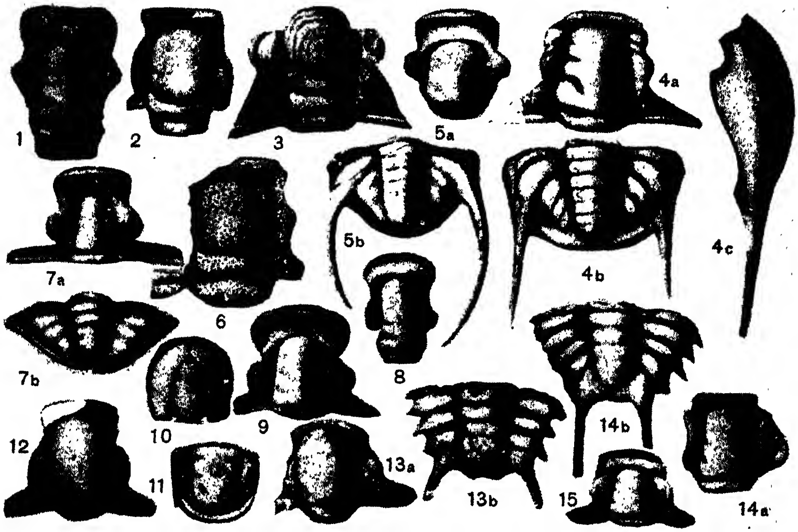

FIG. 22. CAMBRIAN FOSSILS.

1. *Quadraticephalus walcotti* SUN. Uppermost Cambrian. × 2.
2. *Saukia acamus* var. *punctata* SUN. Upper Cambrian. × 2.
3. *Ptychaspis subglobosa* GRABAU. Kaolishan Formation, Upper Cambrian. × 3.
4 a, b, c. *Kaolishania pustulosa* SUN. Kaolishan Limestone, Upper Cambrian. × 2.
5 a, b. *Mansuyia orientalis* (GR.) SUN. Kaolishan Formation. × 2.
6. *Ptychaspis walcotti* MANSUY. Shakuotun Limestone, near Mukden, Upper Cambrian. × 2.
7 a, b. *Changshania conica* SUN. Changshan Shale, N.E. Hopei, Upper Cambrian. a × 2, b × 3.
8. *Chuangia chinensis* SUN. Chaumitien Limestone, Upper Cambrian. × 2.
9. *Chuangia batia* WALCOTT. Kaolishan Formation, Upper Cambrian. × 2.
10. *Agnostus cyclopygeformis* SUN. Kaolishan Formation, Upper Cambrian. × 7.
11. *Agnostus hoi* SUN. Changshan Formation, Upper Cambrian. × 6.
12. *Dolichometopus deois* WALCOTT. Changhia Limestone. Middle Cambrian. × 2.
13 a, b. *Dorypyge richthofeni* DAMES. Changhia Limestone, Middle Cambrian. a × 1½, b × 2.
14 a, b. *Blackwelderia sinensis* var. *linchengensis* SUN. Kushan Shale, Middle Cambrian. a × 2, b × 3.
15. *Ptychoparia leichuangensis* SUN. Manto Shale, Lower Cambrian. × 8.

well-known trilobite, *Redlichia sinensis,* is the characteristic fossil in this formation. Associated with this species are other species of *Redlichia* and *Ptychoparia.* The round form of brachiopod, *Obolella,* together with some gastropods also occurs. Willis and Blackwelder named this series the Manto Formation. Its thickness varies from 100 to 230 m. in north-eastern China. But in the deeper part of the Palæocathaysian geosyncline, such as in the bordering mountains of north-eastern Hopei where the Great Wall stands, the thickness is probably greater and the strata are more calcareous. This shaly and sandy formation, often red in colour, can be traced all along the Taihang and Luliang Ranges down to the Mihsien and Yuhsien districts in central Honan, and to the northern part of Kiangsu and Anhui.

In the central Yangtze Valley greenish-grey and brown shales with the characteristic *Redlichia* fauna are widespread in western and northern Hupeh, and are exposed in the north-eastern foothills of the Lushan, northern Kiangsi. From this central area the *Redlichia*-bearing formation appears to extend in two directions: one to the south-west, and the other to the south-east. The south-western branch starts from the neighbourhood of Hsiangyang, extends past the Yangtze Gorge and south-western Hupeh, and finally reaches the district of Yiliang in eastern Yunnan, probably by way of the Kweichow Plateau and the Omeishan area in south-western Szechuan, where the Lower Cambrian formation consists of sandstones, shales and impure limestones. All over this south-western area the Lower Cambrian is generally concordantly underlain by the Sinian and concordantly overlain by the Lower Ordovician. In the south-eastern area, shales and sandstones, with impure limestones similar to the Lower Cambrian formation of the Lushan, are found in southern Anhui; but they are usually absent from the South-Eastern Uplands.

Thus remnants of the Lower Cambrian formation with its characteristic marine fossils are widely scattered in north-eastern, central and south-western China, indicating the approximate trend of the sea that invaded China during that time. The *Redlichia* fauna is not peculiarly Chinese. It flourished in a vast sheet of epi-continental water which connected western and southern Australia, northern India and China.

The Middle Cambrian is well-developed in western Shantung, and is particularly well exposed in the Changhia district where it is conformably underlain by the Manto Series. Oolitic limestones with layers of shales play a dominant rôle in the lower part, and a greenish shale with beds of contemporaneous limestone-conglomerate represents the upper part of the series. These are locally known as the Changhia Limestone and Kushan Shale respectively. According to Blackwelder, the Changhia Limestone measures some 150 m. thick in its type locality, but the Kushan Shale much less.

These rocks are particularly rich in trilobites. *Ptychoparia* and *Anomocarella* predominate in the lower part. Besides these, *Dorypyge, Damesella* and *Blackwelderia* appear in the higher beds. *Drepanura* (*Fig.* 22), well known as museum exhibits, and *Agnostus,* a blind form, abound in the calcareous layers of the Kushan Shale.

Limestones with the same fauna, often oolitic and sometimes globulitic, varying from 300 to 500 m. in thickness, are widely distributed in South Manchuria, the Western Hills of Peking, and the Taihang and Luliang Ranges in the Shansi Plateau. They crop out at many localities in the south-eastern part of the North China Plain. In the southern part of the middle Tsinling Range only one locality is known, namely Kisinling, where *Bradoria* and Middle Cambrian brachiopods, including the genera *Dicellomus* and *Obolus,* occur in association with *Obolella asiatica,* a form which also occurs in the Manto Formation of Shantung. A *Dorypyge*-bearing sandstone has been found 15 km. south of Ichang. Further south no fossiliferous Middle Cambrian strata are known until we come to Indo-China, where the faunistic character of the rock is somewhat different.

Upper Cambrian is represented in western Shantung by the Chaumitien Limestone, a rather thin-bedded, often slabby, blue limestone, now and then intercalated with intraformational conglomerate known as wurmkalk. The pebbles

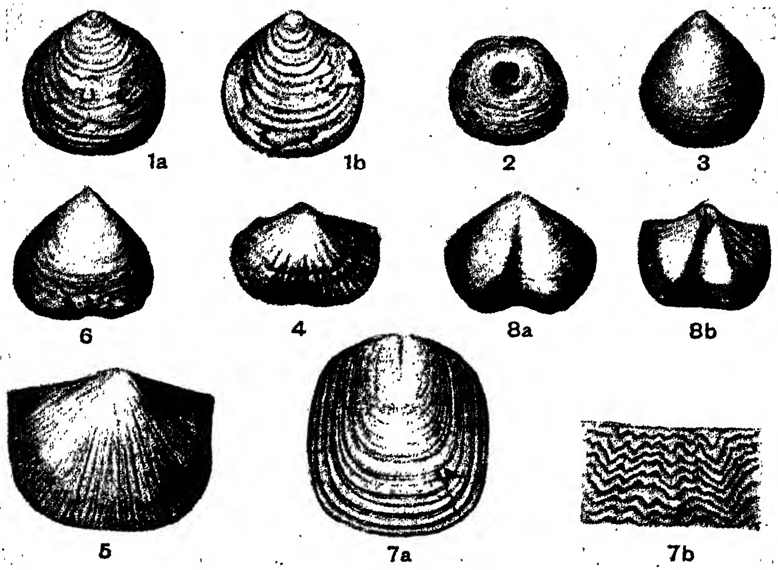

FIG. 23. CAMBRIAN BRACHIOPODS.

1 a, b. *Obolus* (*Westonia*) *leei* SUN. About × 2. a, ventral valve; b, counterpart of the same. Lower Cambrian.
2. *Acrothele cheni* SUN. × 1½. Manto Shale, Lower Cambrian.
3. *Obolus linyuenensis* SUN. × 5. Manto Shale, Lower Cambrian.
4. *Nisusia hayasakai* SUN. × 2. Changhia Limestone, Middle Cambrian.
5. *Eoorthis shakuotunensis* SUN. About × 2. Shakuotun Limestone, near Mukden, Upper Cambrian.
6. *Obolus luanhsienensis* GR. × 2. Fengshan Limestone, Upper Cambrian.
7 a, b. *Lingulella dimorpha* SUN. a, exterior of the shell, × 2; b, growth lines, × 6. Fengshan Limestone, Upper Cambrian.
8 a, b. *Syntrophia orthia* WALCOTT. a, exterior of the pedicle valve, about × 3; b, interior of the pedicle valve, × 2. Kaolishan Limestone, Upper Cambrian.

in this conglomerate are usually small, flattish, somewhat rounded at the edges, and coated with iron oxide, and are often arranged with their long axes parallel to the bedding planes. These pebbles, as well as the matrix in which they are embedded, were derived from contemporaneous limestone. The matrix is sometimes charged with a fairly high percentage of oxide of iron. Wurmkalk is, however, by no means restricted to this formation. It appears sometimes in the Lower Ordovician. *Illænurus, Ptychaspis* and its related genera, and *Plectorthis,* are among the more important forms of fossil that it contains. In Shansi a conglomeratic limestone often succeeds the Middle Cambrian and underlies the Ordovician. The development is thus comparable with that of Shantung. But in the Shansi area the Upper Cambrian limestone now and then contains shales and sandstones. South of the Shantung-Shansi area, Upper Cambrian is probably developed in the Yangtze Gorge and southern Anhui, but the succession has not been worked out.

Formations somewhat higher than, but probably partially equivalent to, the Chaumitien Limestone are known to occur in Shantung, Hopei and South Manchuria. These are named the Changshan and Fengshan Series. They consist sometimes of shales and thin-bedded limestones and sometimes of limestone alone, and are characterized by the presence of certain types of *Ptychaspis, Tsinania, Ceratopyge, Chuangia* and other unfamiliar types of trilobite, such as *Taianocephalus* and *Kaolishania.* Y. C. Sun has tentatively divided the Upper Cambrian of northern China into five zones in the following descending order :—

Fengshanian	5. *Quadraticephalus walcotti* and *Saukia acamus* zone. 4. *Ptychaspis subglobosa* zone.
Changshanian	3. *Kaolishania pustulosa* zone. 2. *Changshania conica* zone. 1. *Chuangia batia* zone.

These uppermost Cambrian beds sometimes conformably succeed, and sometimes partially replace, the Chaumitien Limestone; and in the more northern part of the Palæocathaysian geosyncline, *e.g.* in the vicinity of Mukden, they rest directly upon the Sinian. Between this series and the overlying Ordovician generally, there exists a break, as testified by an erosion surface and basal conglomerate. These higher horizons extend to the Lihcheng district (about 36° 25′ N., 113° 37′ E.) in the southern Taihang Range, as far as this part of the Palæocathaysian geosyncline is concerned.

In the southern part of the Palæocathaysian geosyncline, including the whole area of southern China that was flooded by the Cambrian sea and the southern part of northern China, these higher Cambrian beds have been found only in Hupeh and Anhui. In these regions the Lower Cambrian, and possibly the lower part of the Middle Cambrian, is as a rule immediately overlain by the Lower Ordovician. On the other hand, in the Yangtze Gorge, the Lower Cambrian with the *Redlichia* fauna is overlain by the Ichang Limestone, over 1,200 m. thick, which has been regarded as a Lower Ordovician formation because of the presence of archæocyathids. Archæocyathids are known to occur in unquestionable Cambrian beds elsewhere in the world. It is therefore not impossible that the lower part of the Ichang Limestone represents the uppermost Cambrian. A formation comparable with the Ichang Limestone is developed in the Omeishan area, south-western Szechuan. In Indo-China an Upper Cambrian fauna of northern affinity has been described by Mansuy. In the Spiti district, northern India, both Middle and Upper Cambrian are well represented.

The point of interest is that during Middle Cambrian times southern and south-western China experienced an emergence, while at the same time north-eastern China was still under fairly deep water. The higher Cambrian beds tend to overlap towards the north-east. But during the uppermost Cambrian stage the sea apparently widened to a considerable extent. This sea must have spread as far south as Indo-China. Otherwise the characteristic northern species of *Chuangia* and *Ptychaspis* would not have been found in that area.

That during late Lower Cambrian and Middle Cambrian times the epi-continental seas withdrew to the north, is further recorded in north-western Europe and north-eastern

America. In the Baltic province marine beds of this age persistently overlap towards the north-west until they entirely disappear in central Sweden. In the north-eastern part of the Appalachian geosyncline, or the Acadian trough, the shallow sea was also in continual expansion. At the same time the deeper water in the south-western part of the Appalachian geosyncline, namely, the region to the south of the "Albany axis," transgressed northward, according to Grabau, with an accompanying overlap of successive horizons.

In Upper Cambrian times extensive areas in the southern part of the North American continent were flooded by inland seas. The palæogeographic map of Schuchert illustrates this southern expansion of the epi-continental water with striking lucidity. To the Ozarkian system of Ulrich probably belong some of the sediments formed in this transgressive water.

Post-Cambrian or Intra-Ozarkian Disturbances

The transgression of the early Cambrian sea was probably due to a eustatic or epeirogenic movement accompanied by subsidence in the geosynclinal area. But so far we have failed to detect any tectonic disturbance. During Lower and Middle Cambrian times the sea level in the Palæocathaysian geosyncline evidently fluctuated. Such gentle fluctuations may have continued to the end of the Cambrian. But before the close of that period movements of some importance must have taken place. In South Manchuria, T. Kobayashi recognizes two cycles of erosion within the highest Cambrian formation, which is often characterized by the presence of intra-formational conglomerate. Considerations, however, from the faunistic point of view throw light upon the matter. We have already seen that the Middle Cambrian fauna in the Palæocathaysian geosyncline has almost nothing in common with that of Europe, except a certain form recently discovered in the *Olenus* beds in Sweden and reported to bear some affinity to *Drepanura*. That form might be a descendant from the true *Drepanura* and therefore a representative of early Upper Cambrian. On the other hand, we have indisputable evidence for faunal communication between north-western Europe and China at the close of Cambrian times in the presence of *Dictyonema* in these distantly separated regions. It would therefore appear not unsafe to postulate an earth movement of some importance that served to break down the land barrier at the end of Cambrian or the advent of Ordovician times.

Lower Ordovician Transgression

During early Ordovician times the configuration of the land in the Chinese region was essentially the same as in Cambrian times. The Palæocathaysian geosyncline persisted. The southern part of that geosyncline was, however, probably dried up, at least partly, towards the end of Cambrian times, but the northern part was still under marine waters. It is in this northern part of the Palæocathaysian geosyncline that the sea continued to advance, and the Lower Ordovician fauna flourished. At the climax of this advance of the sea the greater part of that geosyncline was flooded. But the area of maximum subsidence appears to be restricted to a belt that lay from the north-east to the south-west, that is, the trend of the great continental trough that we saw in connection with the Cambrian flood.

Lower Ordovician limestone, often dolomitic, is widespread in South Manchuria, containing, in places, Cryptozoon reefs. It is represented by the Wuting and Kangyao Formations. In the district near the eastern end of the Great Wall, for instance in the Liukiang coalfield, several series of limestones and shales, locally known as the Peilintze, Shimenchai and Liangchiashan Formations, totalling a thickness of more than 530 m., have all yielded typical Lower Ordovician fossils. In the Kaiping Basin, some 70 miles south-west of the last-named locality, the Lower Ordovician is represented by a thickness of 400 m. of limestones, of which the lowest member is the Yehli Limestone. This limestone with its basal conglomerate rests upon an eroded surface of the uppermost Cambrian. It has yielded, among other Lower Ordovician fossils, *Suecoceras* and *Ophileta*. The intercalated shales contain Arenig graptolites, and are characterized by abundant *Dendrograptus* and a variety of *Dictyonema flabelliforme* in the lower horizon, and by

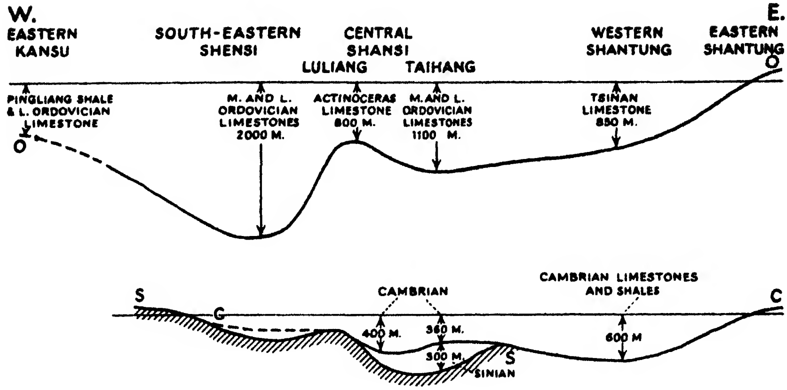

FIG. 24. Cross-sections showing the approximate shape of the changing floor of the northern part of the Palæocathaysian Geosyncline during the Sinian-Ordovician periods, based on the thickness and character of the sediments. OO, Ordovician floor at the end of the Ordovician period; CC, Cambrian floor, and SS, Sinian floor at the end of the Cambrian period. Vertical scale greatly exaggerated.

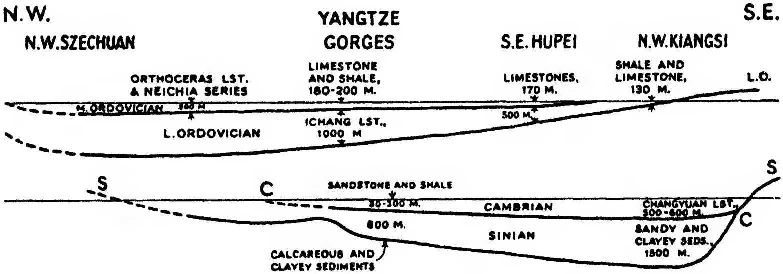

FIG. 25. Cross-sections showing the approximate shape of the floor of the southern Palæocathaysian Geosyncline during the Sinian-Ordovician periods. SS, Sinian floor, and CC, Cambrian floor at the end of the Cambrian period. LO, Lower Ordovician floor at the end of the Middle Ordovician.

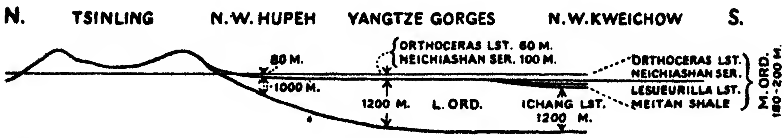

FIG. 26. An idealized section showing the Ordovician formations to the south of the Tsinling, post-Ordovician folding being eliminated.

Dichograptus, Loganograptus and *Desmograptus* in the higher beds.

Further south-west in central China the Lower Ordovician is represented by the upper part of the Ichang Limestone, with a thickness of 1,250 m. In the uppermost part of this limestone occurs *Callograptus,* a *Dictyonema*-like form but with few connecting dissepiments. In the basal part of the same limestone coral-like organisms, ? archæocyathids, occur in abundance. They are associated with *Girvanella,* which is a widely distributed alga generally believed to be of Lower Ordovician age in China. Thus, in spite of its great thickness, the upper part, if not the whole, of the Ichang Limestone seems to belong to the Lower Ordovician. This limestone rests directly upon the Lower Cambrian but without discordance. The Ichang Limestone extends into the Kweichow Plateau. In Meitanhsien in the north-eastern part of the plateau, the same limestone is overlain by the Meitan Shale with *Phyllograptus.*

In central Hunan a series of shales and limestones, locally named the Chiaotingtze Series, aggregates a thickness of no less than 700 m. In this series *Tetragraptus* and *Didymograptus* of Arenig age occur. It is concordantly overlain by quartzitic sandstones and shales, about 400 m. thick, either belonging to the higher stage of the Ordovician or to the Lower Silurian. Lower down in the Yangtze Valley a massive limestone with a characteristic Lower Ordovician fauna is developed in north-western Kiangsi, where it is known as the Wushimen Limestone. In the Nanking Hills it is known as the Lunshan Limestone, and in Chekiang it is called, together with some pre-Ordovician strata, the Inchu Series. Throughout the Central and Lower Yangtze Valley the Lower Ordovician formation is almost entirely marine except for the Inchu Series, which contains a large proportion of terrigenous material. Even the terrigenous deposit disappears towards the South-Eastern Uplands.

In the extreme south, namely in the Sikiang Valley, J. L. Hsu and Y. Chiang mention a dolomite which forms the middle part of their Lungshan Series. This dolomite with crinoidal stems is evidently underlain by a thick sequence of schistose sandstones, slates, phyllites and quartzites probably of Sinian age, and overlain by argillaceous limestones and shales, which are in turn succeeded by graptolite-bearing Silurian. As suggested by Hsu and Chiang, this dolomite is probably of Ordovician age. The stratigraphical sequence given by them would seem to suggest that it belongs either to the Lower or to the Middle Ordovician.

So far we have followed the deep water facies of the Lower Ordovician. From these deeper parts of the geosyncline a shallow sea seems to have spread out over large areas. Thus in the Lower Yangtze Valley many species of *Didymograptus* are found in the Ningkuo Shale in the Ningkuo district, southern Anhui. Some of these species also occur in the province of Chekiang. *Phyllograptus* and *Dendrograptus* occur in shales and shaly limestones in western Kiangsi. All these undoubtedly signify Arenig or Beekmantown age.

In the Ningkuo Shale S. C. Hsu has established two graptolite zones and a number of sub-zones. These are as follows in descending order:—

Zone of *Amplexograptus confertus*.
- Sub-Zone with *Didymograptus fasciculatus*.
- Sub-Zone with *Climacograptus*(?) *gracilicornis*.
- Sub-Zone with *Didymograptus ellesi*.

Zone of *Didymograptus hirundo*.

The lowest zone is followed downward by a shale with *Ogygites*(*?*), which appears to attain a considerable range in the Ordovician, and is therefore useless for zonal purposes.

The Chinese Lower Ordovician fauna constitutes a strange mixture. In *Piloceras, Proterocameroceras, Suecoceras, Ophileta, Tetragraptus* and certain types of *Phyllograptus* we see its unquestioned affinity with that of the Beekmantown of North America; while in the many species of *Didymograptus*, some of the *Amplexograptus*, and the *Callograptus* its close connection with the British Arenig fauna is demonstrated. There is yet a third element, namely the archæocyathids, that adds to the complexity of the fauna. Hitherto, archæocyathids are reported to occur in the Cambrian of Australia, Siberia, and (very doubtfully) the

Durness Limestone of Scotland. But in northern China they seem to be associated with Lower Ordovician forms, and in central China they occur in the basal part of the Ichang Limestone, being associated in the Yangtze Gorge district with *Girvanella sinensis,* believed to be an Ordovician species. From this faunal assemblage it can be readily seen that the Chinese Lower Ordovician waters were in free communication with those of North America on the one hand and those of northern Europe on the other. The centre of communication probably lay in the boreal region. This is especially suggestive when we know that a large area in northern Siberia was under marine waters at that time. Certainly no other centre would be equally facile for the dispersal of the organisms referred to.

In the early stage of the Lower Ordovician transgression we have some stratigraphical evidence in China to show that the higher horizons tend to overlap southward. The same state of affairs is recorded in the north-eastern part of North America, where the phenomena of overlapping and "off-lapping" were lucidly demonstrated by Grabau. In western Newfoundland a great thickness of the Beekmantown and Chazy Limestones rests immediately upon the Lower Cambrian, signifying the expansion of the boreal sea in the initial stage. Traced south-westward to the Champlain-Hudson region, both the Upper Beekmantown and Lower Chazy beds gradually disappear, leaving an ever-widening break between the two. These facts admit no other interpretation but that the Beekmantown sea invaded the area from the north at first and spread southward, until a time when the sea started to retreat northward, leaving the southern deposit to subaerial erosion before it was covered again by the early Middle Ordovician or Chazy sea. A similar overlapping and off-lapping are believed to be demonstrable with the Chinese Lower Ordovician formation. Unfortunately our zonal and mapping work have not been carried out in such detail as to warrant a positive statement. At all events there is no question that the Chinese Lower Ordovician, like its equivalent in the American continent, constitutes a stratigraphical unit of its own. This period of deposition was followed by a crustal movement.

FIG. 27. ORDOVICIAN GRAPTOLITES.

1. *Dendrograptus* cf. *persculptus* HOPK. Aftei SUN. Lower Ordovician, northern Kiangsi. × 1.
2. *Callograptus salteri* HALL. Ichang Limestone, Lower Ordovician. × 1.
3. *Climacograptus bicornis* HALL. Pingliang Shale, Middle Ordovician. × 3.
4. *Climacograptus latus* E. and W. Wufeng Shale, Upper Ordovician. × 5.
5. *Climacograptus supernus* E. and W. Upper Ordovician, S.W. Hupeh. × 5.

The Huaiyuanian Movement

In contrast to the Lower Ordovician fauna which, as already stated, embodies a mixture of faunal elements and shows no provincial character except that due to facial difference, the Middle Ordovician fauna broadly falls into two types. The two life provinces were separated by a belt of land that approximately corresponds to the site of the present Tsinling and its south-eastern continuation, the Nanking Hills. The northern fauna, with *Actinoceras* as its leading member, only rarely commingles with the southern fauna, which is typified by the presence of *Orthoceras*. The northern fauna is clearly of the North American type, essentially comparable with that of the Black River formation; while the southern type is largely the European Llandeilian fauna with a number of species peculiar to China and some Australian forms. There is, however, one physical feature in common. Throughout China, wherever the higher Ordovician beds are developed in superposition with the Lower Ordovician, there is always a stratigraphical break.

The inference is therefore natural that a land barrier, though not necessarily complete, was raised across central China along the present Tsinling and separated the two faunal provinces. So far, however, we have failed to find any stratigraphical discordance between the Lower and Middle Ordovician. There is only one case which deserves attention in this connection. In the Huaiyuan coalfield, an area that lies behind the innermost arc of the Huaiyang Arcs (see p. 303), the Actinoceras Limestone with a basal conglomerate rests discordantly upon a series of limestones, sandstones, and shales interbedded with limestones, in which no fossil has been found. But judging from the lithological character of this series of strata and from the fact that some of them are globulitic, it seems safe to regard them as Middle Cambrian. The unconformity must therefore either represent the late Cambrian or else the post-Lower Ordovician movement. Since there is reason to believe that the Ozarkian disturbances were never so intense as to raise any effective faunal barrier in China, it would seem more natural, in view of the widespread nature of the break between the

FIG. 28. ORDOVICIAN FOSSILS.

Lower and Middle Ordovician, to regard the movement represented by this unconformity as a closing episode of the Lower Ordovician. The post-Lower Ordovician disturbance may thus be called the Huaiyuanian movement.

Middle Ordovician Transgression

Apart from the rising land barrier across central China as a result of the Huaiyuanian movement, the Palæocathaysian geosyncline seems to have remained essentially the same as in Lower Ordovician time. Into that divided geosyncline the Middle Ordovician waters advanced both from the north and from the south. The greater part of China was submerged under the spreading sea. In northern China there was formed the Actinoceras Limestone, a massive, grey, and sometimes reddish-grey limestone rarely containing shaly layers. Because of its long exposure to erosion before it was overlain by younger strata its preserved thickness varies from locality to locality. In South Manchuria it is known as the Ssuyen Formation and contains *Archæo-*

EXPLANATION OF FIG. 28.

1 a, b. *Actinoceras richthofeni* Frech. a, end view of an early part of the shell; b, median longitudinal section. Machiakou Limestone, Middle Ordovician. × ½.
2. *Lophospira morrisi* Gr. Machiakou Limestone. × 1.
3. *Asaphus boehmi* Lorenz. Machiakou Limestone. × 1.
4. *Orthis calligramma* Dalman var. *intercalare* Chang. × 1½.
5 a, b. *Orthoceras chinensis* Foord. a, longitudinal section; b, cross-section. Middle Ordovician. × ½.
6. *Lituites? lii* Yü. Middle Ordovician, S.E. Hupeh. × ½.
7 a, b. *Orthoceras regulare* Schloth. a, longitudinal section; b, transverse section. Middle Ordovician. × ½.
8. *Discoceras eurasiaticum* Frech. Neichiashan Series, Middle Ordovician. × ½.
9. *Vaginoceras wahlenbergi* Foord var. *cylindrica* Yü. Middle Ordovician, S.E. Hupeh. × ½.
10. *Ogygites yunnanensis* Reed. Neichiashan Series, Middle Ordovician. × ½.
11. *Acidaspis huangi* Sun. Neichiashan Series. × ½.
12. *Taihungshania shui* Sun. Middle Ordovician. × ½.
13. *Illænus holmi* Sun. Middle Ordovician. × 1⅓.
14 a-e. *Protocameroceras mathieui* Gr. Peilintze Limestone, eastern Hopei, Lower Ordovician. a × ½, b-e × 1.
15 a, b. *Cameroceras styliforme* Gr. Lower Ordovician. a × ½, b × 1.
16. *Piloceras platycentrum* Gr. Lower Ordovician. × ½.
17. *Archæocyathus chihliense* Gr. Lower Ordovician. × ½.
18. *Eccyliopterus sinensis* (Frech). Lower Ordovician. × ⅓.
19. *Ophileta plana* Gr. Lower Ordovician. × ½.
20. *Suecoceras yehliense* Gr. Lower Ordovician. × ½.

cyathus manchuriensis, *Lambeoceras nassum* and *Bybyoceras fœrstei*. The last-named form also occurs in the Lower Chazy of Oklahoma and the Lyckholm Beds of Esthonia. In the Kaiping Basin, where the limestone is locally named the Machiakou Limestone, its thickness is estimated at 300 m. But in the better preserved regions, such as in parts of Shansi, it sometimes attains 900 m. 300 to 500 m. is the thickness that has been commonly preserved. Usually this limestone rests upon eroded Lower Ordovician or Cambrian, but sometimes on Sinian or even older rocks, thus displaying its transgressive nature. It is generally overlain by the Penchi or Taiyuan Series of Carboniferous age.

Besides *Actinoceras* we find several genera of straight-shelled cephalopods of related type. *Eccyliopterus*, *Lophospira*, *Liospira*, *Maclurea*, *Asaphus*, *Strophomena* and *Orthis calligramma* are among the familiar forms found in the Actinoceras Limestone.

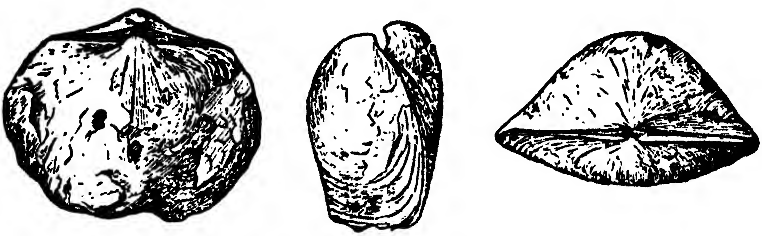

FIG. 29. *Yangtzeella poloi* (MARTELLI). Natural size.

This Actinoceras Limestone is essentially equivalent to the Orthoceras Limestone in southern China. Large *Orthoceras*, often as long as four feet, abounds in this limestone, popularly known as pagoda-stone. It occurs in the Kweichow Plateau, and is extensively distributed in the Yangtze Valley, except in central Hunan, where it appears to be almost completely replaced by the Tienmashan Series, the age of which is, however, uncertain. In the Gorge district the Orthoceras Limestone is only a few metres thick and rests upon the Neichiashan Formation. In the southern foot of the middle Tsinling, it attains 100 m. in thickness. Like that of its equivalent in the north, its thickness varies considerably from locality to locality, but not quite to the same extent.

The Neichiashan Formation, over 100 m. thick, consists of dirty, slabby, argillaceous limestone usually swarming with organic remains. *Triplecia* (*Yangtzeella*), *Clitambonites, Discoceras, Cyrtoceras, Vaginoceras, Asaphus, Illænus, Bathyurus* and many species of *Orthis*, including *Orthis calligramma*, are abundant. This formation appears to extend discontinuously along the Yangtze Valley. Towards the east, it is developed in the Lunshan, near Nanking; towards the south-west it rests upon the *Lesueurilla*-bearing limestone, which in turn overlies the Meitan Shale of Lower Ordovician age in north-eastern Kweichow; but in the Omeishan district, south-western Szechuan, the equivalent of the Neichiashan Formation, though fossiliferous, is mainly composed of coarse clastics. This formation generally rests upon the Lower Ordovician, but is separated from it by a break.

While in the central part of the Palæocathaysian geosyncline the limestones were formed in comparatively quiet waters, the marginal parts of the trough were filled with muddy sediments. The circumstances are similar both in the northern and the southern regions. Thus in the north-west, graptolite-bearing shales or limey shales are found in the Ordos region (about lat. 39° 20′ N., long. 170° E.), including *Didymograptus* and *Dicellograptus* of Lower Llandeilian age, and again in the Pingliang district (about lat. 35° 20′ N., long. 106° 40′ E.), where many genera of graptolites of the Normanskill type occur in a dark-grey, calcareous shale. In the Lower Yangtze Valley the higher Llandeilian zones with *Glossograptus, Climacograptus* and *Dicellograptus* are developed in the Ningkuo district, southern Anhui, and in western Chekiang. These zones are apparently widely distributed in other parts of the Lower Yangtze Valley.

In the Hulo Shale, which directly overlies the Ningkuo Shale of Lower Ordovician age with a break, S. C. Hsu has determined two zones by means of graptolites:—

Upper Zone with *Dicellograptus sextans* and *Climacograptus latus*.

Lower Zone with *Glossograptus hincksii* and *Trigonograptus lineatus*.

Compared with the British development, the break between the Ningkuo and Hulo Shales would seem to cover the whole of the Lower Llandeilian and the lower part of the Upper Llandeilian.

Shales and impure limestones bearing Llandeilian graptolites, *Ogygites*, and cystids related to those of the Baltic province of Russia occur in western Yunnan. They are sometimes overlain by Permian limestone and sometimes by metamorphosed limestone of older Palæozoic age. All along the Yangtze Valley the Orthoceras Limestone is often in direct contact with the Silurian. Between them there is always a stratigraphical break. Consequently a varying thickness of the Orthoceras Limestone is preserved. The highest horizon of the Ordovician, the Ashgillian, represented by *Climacograptus latus* and *C. supernus*, is so far only known in western Hupeh and southern Anhui.

The northern Chinese sea of Middle Ordovician times was undoubtedly in communication with the Black River or Trenton sea of North America. The passage-way lay across Siberia, where a large area was flooded by the Middle Ordovician sea in which also flourished a fauna of the boreal type. The southern Middle Ordovician sea was barely connected with the northern water. Instead, it extended towards the south-west, past Upper Burma, then probably joined the Himalayan geosyncline. Further west, this inland sea was evidently in communication with the European waters of the time.

From these facts it appears fairly obvious that a vast marine flood took place in China in Middle Ordovician times. But it is by no means clear as to the direction in which the sea advanced. If, however, we may judge the depth and extent of the inland seas by the nature and thickness of the limestones formed in them, it would seem that the Actinoceras sea of the north was far more extensive and persistent than the Orthoceras sea in the south. This inference, together with the fact that the faunal elements in the Actinoceras Limestone are dominantly of the North American type, would indicate an advance of the marine water from the boreal region.

Conditions in North America seem to warrant a similar conclusion. We know that during the Chazy stage a great flood of Arctic water came upon the interior of North America. This flood continued to, and was superseded by, the Black River or Trenton transgression, which likewise washed the continent from the north to the south. This spreading of the boreal sea is clearly shown by the overlapping tendency of the deposits that were formed in each step of its advancement. Palæontologists seem to agree that the northern epeiric sea of North America moved so far south that it finally became confluent with the southern waters.

The movement of the epeiric seas in Europe is more difficult to determine, because of the west and east trend of the then Baltic and Mediterranean troughs. Nevertheless, the fact that the Llandeilian is present both in south-western Europe and in the British Isles, and that the succeeding stage, namely the Caradocian, is only present in the northern trough but is absent from the south-west, indicates an elevation of the ocean surface in the more northern region towards Upper Ordovician times. It is to be noted that an earth-movement was already in evidence at the end of the Middle Ordovician epoch. The expansion of the boreal sea after the initiation of this movement is particularly well demonstrated in the northern part of North America by the Richmond transgression, which, though apparently a duplication of the Trenton flood, had never spread so far south as in Middle Ordovician times. The presence of Ashgillian in southern China suggests that towards the closing stage of the Ordovician south-eastern Asia was at least temporarily and partially flooded by marine waters.

Late Ordovician Disturbance

A great change was brought about in northern China towards the end of Ordovician times. That broad and extensive continental trough, the Palæocathaysian geosyncline, which had been in more or less continuous existence since Sinian times, was now upset. The whole of northern China, namely the area to the north of the Tsinling Range, was uplifted as a block. It is a firmly established fact that throughout the North China massif, including Manchuria and Korea, the Ordovician strata are separated from the overlying Carboniferous by a prolonged gap. We do not know precisely what happened to this vast territory during that long period of time; we do know, however, that there exists no trace of Silurian sediments in this area, except for a limestone of doubtful Silurian or Devonian age in the northwest, and that above the Ordovician the Carboniferous lies concordantly. The latter fact clearly signifies that northern China behaved essentially as a block. It may be surmised that the absence of Silurian was due not so much to non-deposition but rather to post-Silurian and pre-Carboniferous erosion. This is not impossible, but it seems rather strange how erosion can have effected such a clean sweep even in the odd corners of a local basin or a down-faulted block. The probability is that no deposit was formed in Silurian times throughout that area.

In southern China, too, we have already adduced evidence that there exists a break between the Ordovician and the Silurian. Although we have so far failed to detect any marked discordance between the two systems of strata, the stratigraphical facts leave little doubt as to the cessation of deposition, and consequently as to the disturbance that brought about the result. This disturbance may be correlated with the Taconian of North America, although the movement was perhaps never locally so intense as in the Taconic Mountains.

Silurian Transgression

The elevation of northern China at the end of Ordovician times was sharply contrasted by a general subsidence in the southern part of the country. The northern belt of the Tsinling zone appears to have behaved as the fulcrum between the rising and sinking blocks. To the south of this dividing line Lower Silurian shale, often intercalated with sandstones and rarely with beds of conglomerate, is extensively developed. This fissile shale, which may be black, greenish-grey, but more often buff to brown in colour, and rather uniform in composition, attains a thickness of more than 1,000 m. It is known in the Yangtze Valley under various local names. In western Hupeh and along the southern flank of the Tapeishan it is generally termed the Sintan and Fuchih Shales, and has numerous graptolites. In the Nanking Hills, it is known as the Kaochiapien Shale, in which occur *Calymene, Phacops, Cheirurus, Proetus*, etc., in the lower horizons, and graptolites in the higher. This formation is generally underlain by Lower or Middle Ordovician, and concordantly overlain by Lower Carboniferous. But in central Hunan it is unconformably overlain by Middle Devonian.

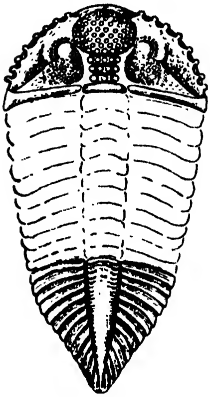

FIG. 30. *Encrinurus* (*Coronocephalus*) *rex* GR. Natural size. Fuchih shale. (After GRABAU.)

Akidograptus (*Cephalograptus*) occurs in the Lower Yangtze Valley, representing the Lower Birkhill of the British development. Higher up in the sequence many species of *Monograptus* characterize the Middle Birkhill, Tarannon and Lower Ludlow Stages. A richly decorated trilobite, *Encrinurus* (*Coronocephalus*) *rex* (*Fig.* 30), and a small and simple-ribbed *Spirifer*, *S. hsiehi*, also abound in certain facies.

In southern Anhui and in the Nanking Hills S. C. Hsu has established the following zones arranged in descending order:—

	Zone with *Monograptus leei*.
Kaochiapienian	Zone with *Akidograptus* (=*Cephalograptus*) *ascensus*.

The Kaochiapienian Stage is considered to be equivalent to the Birkhill or the Lower Valentian of the British development. The absence of the Wenlock stage, which is characterized by *Cyrtograptus*, is a notable feature in the Chinese development.

The same Valentian fauna occurs in the Sikiang Valley, where an alternating sequence of shales and sandstones overlies the Ordovician, and is unconformably overlain by Devonian continental beds. A graptolite-bearing formation of Lower Silurian age is also known in western Yunnan. Another facies of the Lower Silurian is known in eastern Yunnan as the Mientien Series. All these Lower Silurian beds were evidently deposited in shallow water, for they often alternate with sandstones or even conglomerates.

A deep-water facies of the Lower Silurian formation is only known to occur on both sides of the main range of the Tsinling running approximately in an east-west direction. This is the Shiwengtzu Limestone, a massive limestone often containing bands of flint, and having a thickness of 700 m. It is overlain by the Devonian limestone, which begins with a basal conglomerate. Thus we see some evidence of a rather deep trough which existed in Lower Silurian times in the mid-western part of the Tsinling zone. Whether this trough was the site of a single mediterranean sea, or was partially separated into two parallel troughs by an east-west strip of old land, is unknown. The important fact to be noted is that at the end of Ordovician times the Tsinling geosyncline came into existence when the Palæocathaysian geosyncline partially disappeared.

Arms of clear water were stretched out on the southern side of the Tsinling geosyncline. Thus in western Hupeh such familiar brachiopods as *Dalmanella* and *Pentamerus*, together with the widely distributed corals, *Halysites*, *Favosites*, etc., have been found in a marly limestone. Further west along the Tsinling zone, many cosmopolitan brachiopods and corals were collected by Richthofen in the neighbourhood of Ningkiang (about lat. 32° 45′ N., long. 106° 10′ E.) from Lower Silurian limestones which are intercalated with shales. They have been long made familiar in palæontological literature.

The highest Silurian beds are only known in the southwestern part of the country. In eastern Yunnan the uppermost Silurian is represented by thin-bedded limestones intercalated with shales known as the Miaokao Formation, some 400 m. thick. It yields a peculiar fauna such as *Spirifer tingi*, *S. bourgeoisi*, *Hormotoma* and *Leperditia*. In the higher horizons the rock is often crowded with fish remains. This highest stage of the Silurian probably only extends over a limited area to the north of eastern Yunnan. But it

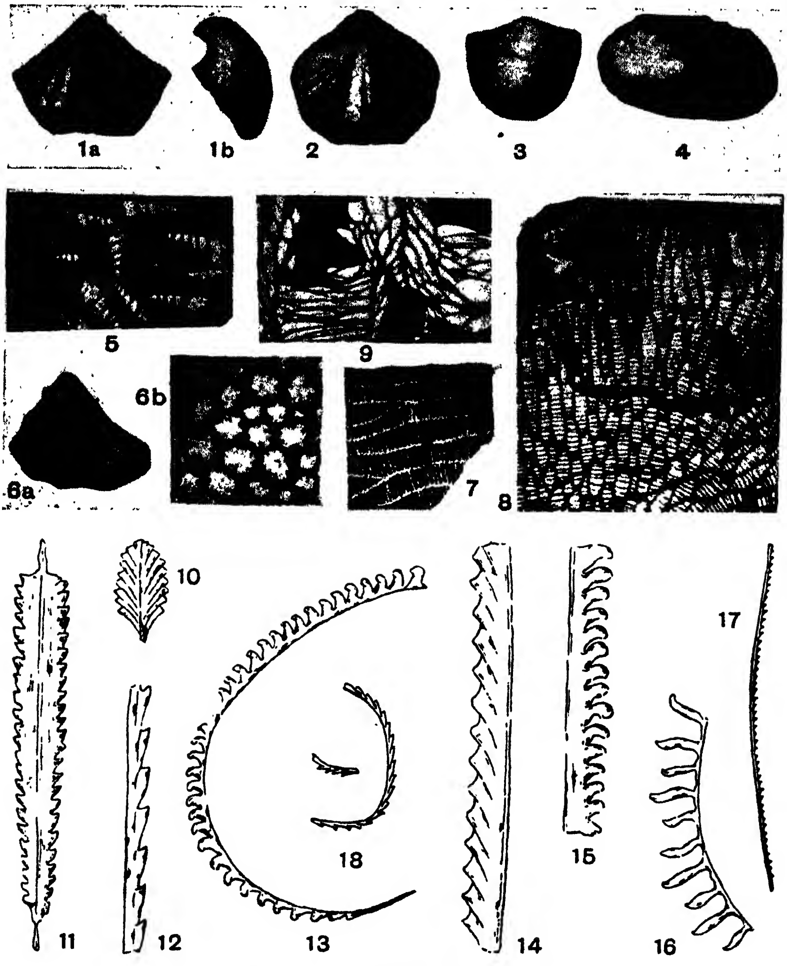

FIG. 31. SILURIAN FOSSILS.

1 a, b. *Spirifer bourgeoisi* MANSUY. Miaokao Group. Upper Silurian. × 2.
2. *Spirifer* (*Eospirifer*) *tingi* GR. Miaokao Group. × 2.
3. *Dalmanella* cf. *basalis* (DALMAN). Mientien Group, Lower Silurian. × 2.
4. *Leperditia tingi* GR. Miaokao Group. × 3.
5. *Hormotoma kutsingensis* GR. Miaokao Group. × $\frac{2}{3}$.
6 a, b. *Favosites* cf. *gothlandicus* LAM. Malung Limestone, Lower Silurian, eastern Yunnan. a, natural longitudinal section, × $\frac{2}{3}$. b, cross-section, × $2\frac{2}{3}$.
7. *Favosites* cf. *gothlandicus* forma *forbesi* E. and H. Enlarged thin section. Upper Silurian, eastern Yunnan. × $2\frac{2}{3}$.

spreads into Indo-China. As has been well remarked by A. W. Grabau, this fauna with its dwarfed habit is comparable with the Manlius fauna of North America. The Miaokao Formation rests with a distinct break upon the Lower Silurian, and is overlain by Middle Devonian.

The Lower Silurian sea of southern China had no direct connection with that body of water which had flooded the northern part of Siberia since the end of Ordovician times. It was, however, in communication with the Lower Silurian waters of Europe, probably through the pathway of the Himalayan geosyncline and central Asia. In north-western Europe, more particularly in the British Isles, the lithological character of the Silurian rocks from the Mayhill Sandstone upwards to the Aymestry Limestone generally indicates a continual deepening of the sea. A similar phenomenon is observable in the Niagaran Group of North America, where the Medina Sandstone is succeeded upwards by shales and limestones culminating in the development of the Lockport Limestone and the Guelph Dolomite. These developments characterize the expansive nature of the northern epeiric seas in the early part of Silurian times. As we have already seen, the southern flood recorded in China was only a shallow sheet of water which often became dry, except in the deep trough of the western Tsinling. More significant is the fact that in spite of a diligent search we have so far failed in China to discover the Wenlock stage. On the contrary, the shallow-water facies of the Wenlock stage is extensively

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EXPLANATION OF FIG. 31 (*continued*).

8. *Favosites gothlandicus* forma *forbesi* var. *kweitingense* GR. Upper Silurian, Kweichow. × $\frac{2}{3}$.
9. *Omphyma glomerata* GR. Upper Silurian, Kweichow. × $1\frac{1}{3}$.
10. *Petalograptus minor* ELLES. Lungma or Fuchih Shale, western Hupeh, Lower Silurian. × 2.
11. *Diplograptus* (*Mesograptus*) *modestus* LAPW. Lungma Shale, Lower Silurian. × 2.
12. *Monograptus incommodus* TÖRNQ. Kaochiapien Shale, near Nanking, Lower Silurian. × $3\frac{1}{3}$.
13. *Monograptus communis* (LAPW.). Lungma Shale. × 2.
14. *Monograptus regularis* TÖRNQ. Lungma Shale. × $3\frac{1}{3}$.
15. *Monograptus sedgwicki* (PORTLOCK). Lungma Shale. × $3\frac{1}{3}$.
16. *Monograptus* (*Rastrites*) *hybridus* (LAPW.) Lower Silurian, western Hupeh. × $3\frac{1}{3}$.
17. *Monograptus acus* LAPW. Taiping Shale, Anhui. × $\frac{2}{3}$.
18. *Monograptus leei* HSU. Lower Silurian. × $\frac{2}{3}$.

developed in Britain and North America, being represented by limestones and calcareous shales, while in Britain banded mudstones accumulated in the deeper-water tracts. Evidence of this kind would seem to point to the conclusion that the epeiric seas in the Northern Hemisphere shifted northward in Lower and Middle Silurian times according to the British standard of classification.

This northern retreat of the epeiric water left many parts of the continents to sub-aerial erosion. Then followed another advance of the sea to the south which was heralded by a part or the whole of the Monroan and Manlius formations in North America, and the Miaokao Group in south-western China, but is represented by a break between the Lower and Upper Ludlow and some shallow water or even continental deposits in north-western Europe. After this southern expansion of the sea the Caledonian movement began to take place.

Caledonian Movement

For lack of sedimentary record we do not know what happened to northern China at the close of Silurian times, except in the south-eastern extension of the Nanshan and along the northern belt of the Tsinling, where there are signs of post-Silurian disturbance. The block type of structure prevailing in that region seems to argue for the inference that it had behaved as a massif. In south-eastern China the Silurian shale is generally overlain by the Wutung Sandstone of Lower Carboniferous age. There is no pronounced discordance between the two, although detailed mapping over wide areas may reveal their unconformable relation. At all events, south-eastern China was lifted above water in late Silurian or post-Silurian times.

More positive evidence of orogenic movement at the close of Silurian times is, however, available in central Hunan, the Nanling Range, and the Sikiang Valley. In the first-named region the Middle Devonian is separated from the Silurian by a flagrant unconformity. A similar relation is observed in the Wuling Ranges which form the central part of the Nanling, and in the Kaoyao district in the Sikiang Valley, where the Tinghushan Series with its basal conglomerate lies unconformably upon the graptolite-bearing Silurian. Correlation on a lithological basis and comparison of stratigraphical development in the neighbouring areas leave little doubt as to the lower or early Middle Devonian age of the Tinghushan Series. This orogenic zone can be traced westward into the south-eastern part of Kuangsi where the Ordovician and Silurian rocks are intensely folded with the axes of the folds running nearly east-west. Upon the eroded surface of these highly folded rocks lies the Upper Devonian limestone.

These facts, together with the evidence of Caledonian movement in central Asia, Transbaikalia and in Indo-China, will serve to demonstrate the powerfulness and extension of this mid-Palæozoic orogenesis over the greater part of the Asiatic continent.

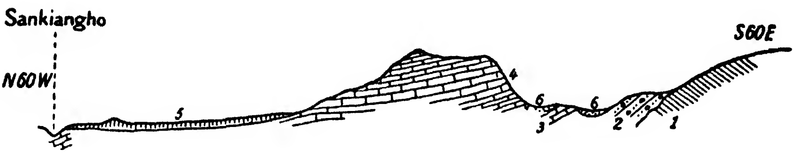

FIG. 32. Section to the south-east of Changan, Yunghsien, northern Kuangsi, showing the pre-Devonian unconformity due to Caledonian movements. (After C. LI.)

1. Lienhushan Series—Black phyllitic shale, probably Ordovician.
2. Liukiang Series—Reddish brown conglomeratic sandstone and sandy shale (Middle Devonian).
3. Black shale interbedded with black thin-bedded limestone (Middle Devonian).
4. Kuhua Limestone — Thick- and thin-bedded grey limestones merging upward into whitish massive limestone and pinkish thin-bedded limestone.
5. Red clay.
6. Alluvial deposit.

DEVONIAN TRANSGRESSIONS

Under the stress of the Caledonian Revolution China as a whole was elevated to a wide expanse of land. Upon this land we can indirectly recognize certain dominant features. The North China massif essentially behaved as a block which undoubtedly went through an uplifting movement, but had never suffered much folding except perhaps along some of the old-established orogenic zones, including its south-western margin. The entire absence of Devonian strata and the generally gentle inclination of the Ordovician beds in that region bear witness to that effect. The Tsinling Strait, which must have been bordered by a highland or mountain range on its northern side, emptied its marine waters because of a general rise of the whole region. The depressed zone seems however to have retained its trough-like form. South-eastern China was raised to a highland; and south-western China was folded into mountains. To the south of the present Sikiang Valley the Caledonian mountain ranges appear to run approximately in an east-west direction. Such is a simplified picture of the relief of the country when the Caledonian Revolution had done with it.

Subaerial denudation continued for a time, and the mountainous area was reduced to one of moderate or even low relief. Into this worn-down area of south-western China the Devonian sea made its way. The Lower Devonian was essentially a period of erosion and of continental deposits, in which occur plant remains that are referred by Halle to *Arthrostigma*. Only in the Chutsing district, eastern Yunnan, are some shells, questionably identified with *Sieberella sieberi* and *Spirifer jouberti* of the Coblenzian of Europe, reported to occur in marly and sandy beds that overlie the Upper Silurian with apparent conformity. Elsewhere in south-western China the Lower Devonian is represented by sandstones, some 600 feet thick.

A sandstone named by V. K. Ting the Lunghuashan Sandstone, 200 m. thick, probably essentially equivalent to the above-mentioned formation, is rather well developed in eastern Yunnan and Kuangsi, while another thick series amounting to no less than 3,000 m. of quartzite with basal conglomerate was observed by Huang on the southern side of the western Tsinling. These clastics are in direct contact with the Silurian belt, and are followed by Middle Devonian limestones. This is practically all that we know of the Lower Devonian development in China.

Lower Devonian is not only poorly developed in China, but is also not at all well represented in Asia. In that vast area to the north of China, fossiliferous Lower Devonian

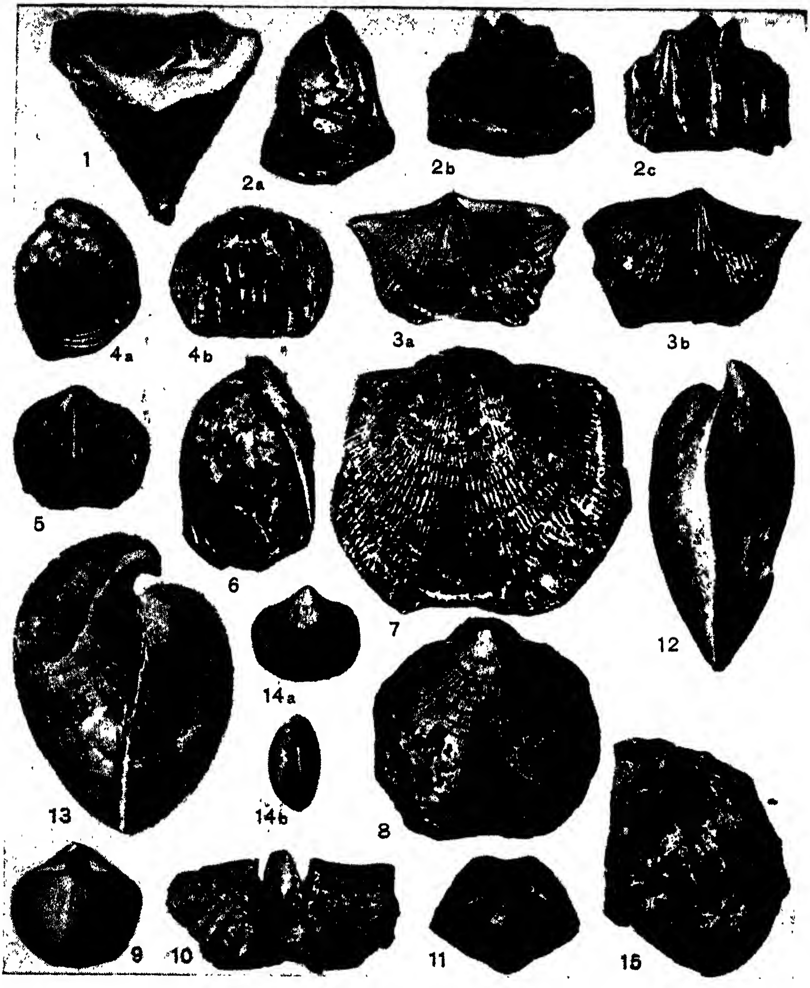

FIG. 33. DEVONIAN FOSSILS.

1. *Calceola sandalina* var. *shuimokouensis* CHI. Early Middle Devonian, west of Chuanhsien, N.W. Szechuan. × 2¼.
2 a, b, c. *Yunnanellina hanburyi* (DAV.). Yaoso Group, Upper Devonian. × 1½.
3 a, b. *Spirifer sinensis* GR. Upper Devonian. × ¾.
4 a, b. *Hypothyridina parallelepipeda* (BRONN). Middle Devonian, Hochih, Kuangsi. × 1½.
5. *Schizophoria macfarlanii* var. *kansuensis* GR. Middle Devonian. × ¾.
6. *Pugnax pugnus* var. *sinensis* GR. Middle Devonian. × 1½.
7. *Atrypa desquamata* mut. *magna* GR. Middle Devonian. × ¾.

has been found only in the Kusnezk Basin, the Salair Mountains, and south-western Altai. Further south-west, in Turkestan and northern Afghanistan, marine Lower Devonian strata occur to some extent. The faunas found in these districts show affinity with the Lower Devonian faunas of Bohemia and the Ural region. Still further south-west a shoaling Lower Devonian sea appears to extend from the Bosphorus north-westward across south-eastern Europe, and on to the Rhine province of Germany where the Coblenzian attains its classical development, though of a shallow-water facies. The bodies of water on the southern part of the Eurasian continent in Lower Devonian times are evidently of restricted extension. On the contrary the northern part of the Uralian geosyncline was subjected to a rather extensive flood.

A similar phenomenon is observed in the north-eastern part of the North American continent. At the end of Silurian times the Appalachian trough was occupied by the Manlius Sea which, according to Grabau, was open both to the north and the south. With the commencement of the Devonian period the sea continued to move northward. Consequently the Helderbergian Formation, limestones with subordinate shales, thickens towards the north-east. In the Gaspé Peninsula, eastern Canada, the Lower Devonian Limestones total a thickness of 2,000 feet. Only the lower part of this limestone series corresponds to the Helderbergian of New York. It is believed from faunal analysis that the northern retreat of water went so far as to leave the southern entrance of the geosyncline uncovered by water at the end of Lower Devonian times.

EXPLANATION OF FIG. 33 (*continued*).

8. *Schizophoria striatula* mut. β GR. Middle Devonian, western Tsinling. × 1½.
9. *Emanuella takwanensis* (KAYSER). Middle Devonian, eastern Yunnan. × 1½.
10. *Spirifer tonkinensis* MANSUY. Early Middle Devonian. × ¾.
11. *Cyrtiopsis intermedia* GR. Upper Devonian. × 1½.
12. *Stringocephalus burtini* DEFRANCE. Middle Devonian, Kuangsi. × ¾.
13. *Stringocephalus obesus* GR. Middle Devonian, eastern Yunnan. × ¾.
14 a, b. *Rhipidomella kutsingensis* GR. Middle Devonian, eastern Yunnan. × ¾.
15. *Gephyroceras intumescens* BEYRICH. Early Upper Devonian, Chaohua, N.W. Szechuan. × ¾.

The sea began to advance in early Middle Devonian or Eifelian times. We will first examine the records of this advancing sea in China, and then discuss how the movement of that sea was connected to, or comparable with, other epi-continental seas of the time.

The researches of V. K. Ting, C. C. Tien and A. W. Grabau have contributed much to our understanding of the movement of the Devonian sea in south-western China. In the first stage, the sea covered the southern part of the south-western area, namely, Kuangsi and Yunnan, including Indo-China. In Kuangsi a series of shales and sandstones, named the Tangkou Formation, over 300 m. in thickness, was laid down in this Eifelian sea, in which flourished *Spirifer tonkinensis* and *Calceola sandalina.* The latter species has not only been reported from Indo-China and eastern Yunnan, but a variety of it has also been collected from north-western Szechuan.

From this stage on, this epi-continental sea moved northward carrying with it a later Middle Devonian or Givetian fauna which is characterized by the presence of *Leptostrophia* and the well-known *Stringocephalus burtini* and its related forms. The Peima Shale in Kuangsi, and the Pangchai Sandstone, 150 m. thick, were deposited in this advancing sea. This southern sea continued to spread so that the Tungshan Limestone was deposited in Yunnan, the Tungtang and Kuhua Limestones in Kuangsi, the Chipao Limestone in Kweichow, the Tiaomachien (Chaomachien) Series in Hunan, the lower part of the Suimago Series in Szechuan, and the upper part of the Kiangyou Limestone and the Maoerchuan Formation in the western Tsinling geosyncline.

C. C. Tien recognizes several zones and sub-zones in the Tiaomachien Series. They seem to be well-defined as far as central Hunan is concerned. The several zones are as follows in descending order:—

Zone of *Leptostrophia mccarthyi.*

Upper sub-zone. Several species of *Productella* of small size.

Middle sub-zone. *Stringocephalus burtini* var. and *Emanuella takwanensis.*

Lower sub-zone. *Schizophoria striatula* and *Atrypa desquamata* var. *hunanensis*.

Zone of *Atrypa auricurita, Schizophoria striatula* mut. β and *Rhipidomella* cf. *kutsiangensis*.

Zone of *Spiriferina subcristata* and *Meristella* cf. *tumida*.

Zone of *Cyrtolitopsis ornatissimus* and *Schizodus sublugonalis*.

It is of some importance to note that, at the close of this stage which is characterized by *Stringocephalus obesa*, the sea area evidently experienced some disturbance resulting in the formation of barren sandstones or shallow-water deposits. Thus in eastern Yunnan was formed the Kwahsinshan Series, largely composed of terrigenous material; in Kweichow the unfossiliferous Sungchiachiao Sandstone, 120 m. thick; in Kuangsi several series of shallow-water beds known under various local names; in Hunan the Shehushan Sandstone, 100 m. thick, often characterized by ripple-marks and rain-prints. In some of these formations and in the beds overlying the barren sandstones mentioned above true *Stringocephalus burtini* appears. These *burtini*-bearing beds are well developed in Kweichow, and are known as the Chiwochai Limestone, 180 m. thick. The Chitzuchiao Limestone (300 m. thick) contained in the Shihyenpu Series of central Hunan evidently represents the same horizon. Marine formations with this characteristic fossil or its equivalents are developed in Yunnan, Kuangsi, and northern Szechuan.

A temporary and partial withdrawal of water followed. This is evidenced by the coarse sandstones and shales, about 160 m. thick, that form the upper part of the Shihyenpu Series in central Hunan, which evidently lay near the shore of the inland sea. Further west, in Kweichow, marine deposition went on without interruption. Then came on the Upper Devonian or Frasnian transgression with a remarkable fauna of modified European type, such as *Sinospirifer sinensis,* a form undoubtedly related to *Spirifer verneuili, Hypothyridina cuboides,* etc. This stage is represented in eastern Yunnan, Kuangsi, Kweichow and central Hunan by a series of interbedded sandstones, shales and limestones. It is known in Kweichow as the Wangchengpo Series, 250 m. thick, and in Hunan as the Shetienchao Series, having a total thickness of no less than 220 m. The latter contains a *Manticoceras* fauna.

The lower part of the Upper Devonian is conformably succeeded by the highest Devonian formation corresponding, in point of time, to the Famennian of Europe. This uppermost stage of the Devonian, with numerous species of *Yunnanella* and *Sinospirifer,* is represented in Yunnan, Kuangsi and Kweichow by limestones or other kinds of marine sediment, but towards the north-eastern part of Hunan, the marine strata are laterally replaced by the Yohlu Quartzite, which attains a maximum thickness of 300 m. near Changsha, the capital of Hunan Province. Lower down in the Yangtze Valley and in the northern part of the

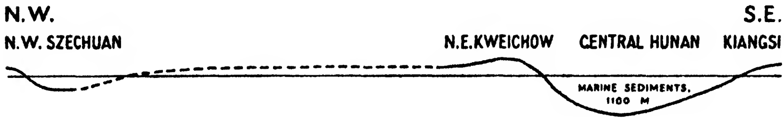

FIG. 34. A hypothetical section of the Devonian floor at the end of the Devonian period.

South-Eastern Uplands isolated exposures of a group of quartzose sandstones have been observed over a wide area. Some of them have yielded Lower Carboniferous plants, but others are unfossiliferous. It must be held as an open question whether some of those quartzites may not represent the Devonian, as was supposed by Richthofen.

The early Middle Devonian sea which flooded south-western China was evidently connected with the Eifelian waters of Europe by way of the Shan States, the Himalayan geosyncline, northern Iran and Armenia. All along this southern water-way the *Calceola* sea drowned many areas that stood above the Lower Devonian water. This southern sea probably sent two arms into the north. One of these sea arms reached the Kusnezk Basin, where the *Calceola* fauna is essentially of the European type. Whether this eastern arm of the sea extended northward by way of western China or central Asia is not known with certainty. The western arm joined the Uralian geosyncline probably by way of southern Russia. It is significant to note that while the southern sea was expanding, the northern water was evidently undergoing contraction: for in the Altai and the Urals, where the Lower Devonian is represented by marine deposit, the early Eifelian is absent or represented by barren sandstone.

It has been generally recognized that the coral fauna of the so-called Upper Eifelian in the western Urals has little in common with the *Calceola* fauna of Europe, but bears some affinity with the Onondaga fauna of North America. As in the western Urals, the Onondaga Limestone of North America is generally underlain by shallow water or continental deposits, such as the Schoharie, Esopus and Oriskany formations. It would thus seem that the retreat of boreal waters in early Eifelian times and the expansion of boreal waters in later Eifelian times similarly affected Eurasia and North America, though the inland sea in the latter continent was far more extensive.

The movement of the Eifelian waters in south-western China was precisely in a reverse order. We have seen evidence that the Eifelian sea continued to expand up to the *Stringocephalus obesus* stage, then a retreat of the marine waters followed, resulting in the deposition of sandstones in Kweichow and Hunan. On these sandstones, which yield fossils of the Givetian stage, again rest marine beds with *Stringocephalus burtini*.

The Chinese Givetian waters seem to form a part of a great trans-continental sea which connected the Indo-Pacific region with the boreal province. At the beginning of Givetian times, this epi-continental body of water showed some tendency to shift northward, causing an extensive flood in Mongolia, central Asia and the Russian Platform. But later in the Givetian epoch the Chinese sea deepened appreciably, as evidenced by the formation of limestones in the south-western provinces. In these provinces and in Kansu *Stringocephalus burtini* and its related species occur in association with forms that show some affinity with the Upper Devonian fauna, such as varieties of *Atrypa desquamata*, *A. aspera, Hypothyridina cuboides, Pugnax pugnus*, etc. A more or less contemporaneous expansion of the inland sea in the North American continent was heralded by the development of the Hamilton group and a southerly invasion of the Dakota sea into which *Stringocephalus burtini* freely migrated.

This temporary southerly expansion of the Givetian sea through continental path-ways was soon succeeded by a partial withdrawal of water in south-western China and central Asia, and a distinct spreading of boreal water, in which flourished the famous *intumescens* fauna with *Manticoceras* (*Gephyroceras*) *intumescens* as its leading element. The fact that this fauna also occurs in Europe, in the Sahara, the Urals and Timan, and the north-western part of North America, but that in the southern region so far it is only known to occur in a shoaling water in central Hunan and northern Szechuan, is an eloquent proof of the widespread nature of the boreal sea at the beginning of Frasnian times.

The third wave of marine invasion into south-western China is marked by the appearance of a group of *Spirifers* that are undoubtedly modifications of *Spirifer verneuili* of Europe. This group of *Spirifers* is known in China as *Sinospirifer*, with *S. sinensis* as its leading type. At this stage, it is almost beyond doubt that all faunal communication between China and the Arctic was severed. The European type of fauna must have wandered into the Chinese waters by way of the south. The Chinese Upper Devonian fauna therefore enjoyed the privilege of specialization under semi-isolated conditions. In that way the *Yunnanella* fauna arose. Before the end of the Devonian period, the sea contracted and became shallow in south-western China. On the other hand the boreal region was flooded in the latter part of Famennian times, when the *Clymenia* fauna arose and migrated even as far south as Oran, Sahara. This fauna, like its predecessor, the *intumescens* fauna, flourished not only in the northern region of Eurasia, but was also equally well developed in the northern inland sea of the North American continent.

Liukiang Disturbance

Throughout the Devonian formation we have noticed stratigraphical facts that indicate fluctuation of sea level, and that the fluctuation was especially marked at the end of Eifelian or the beginning of Givetian times. This was followed by a partial and temporary retreat of the epi-continental sea. Another flood occurred in Frasnian times and seems to have continued down to the end of the Devonian period. No evidence is, however, available of any disturbance of tectonic order, nor is there any evidence for a brisk change in faunal succession, except for the rather sudden appearance of the striking *Stringocephalus*. On this palæontological ground and on the evidence for a temporary withdrawal of water at the end of the *burtini* stage we might be justified in distinguishing a minor cycle of transgression and regression from the other two cycles of more extensive nature.

Positive proof of a tectonic movement within Chinese territory is not available until we come to the end of the Devonian period. Mention has been made that the Lower Carboniferous quartzose sandstone in the Lower Yangtze Valley often comes to rest directly upon the Silurian shale, and that south-eastern China stood as a highland for the most part of, if not the entire, Devonian period. To transform such a highland into an extensive site of deposition means a profound change in the configuration of the land-surface of the country. This, however, does not definitely prove that there occurred a tectonic movement. More illuminating is the case in Liuchow, central Kuangsi, where the Lower Carboniferous actually rests discordantly upon the Devonian. For this reason S. Chu proposes to call this post-Devonian disturbance the Liukiang movement, which, in point of time, appears to correspond to the Marsic phase of the Bretonian of Stille.

Lower Carboniferous Transgressions

After the Liukiang movement the North China massif still stood above water; the Tsinling geosyncline essentially persisted: south-eastern China was reduced to a peneplain

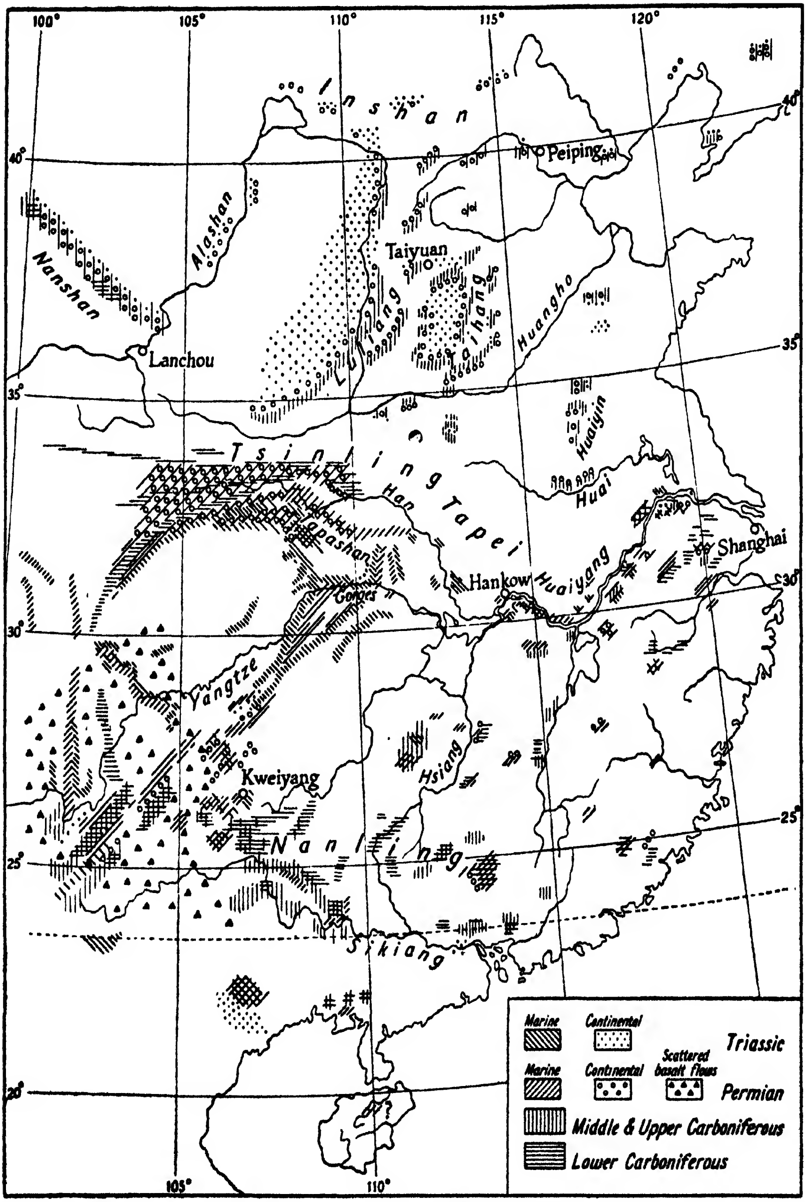

FIG. 35. Map showing the distribution of Carboniferous, Permian and Triassic deposits in China.

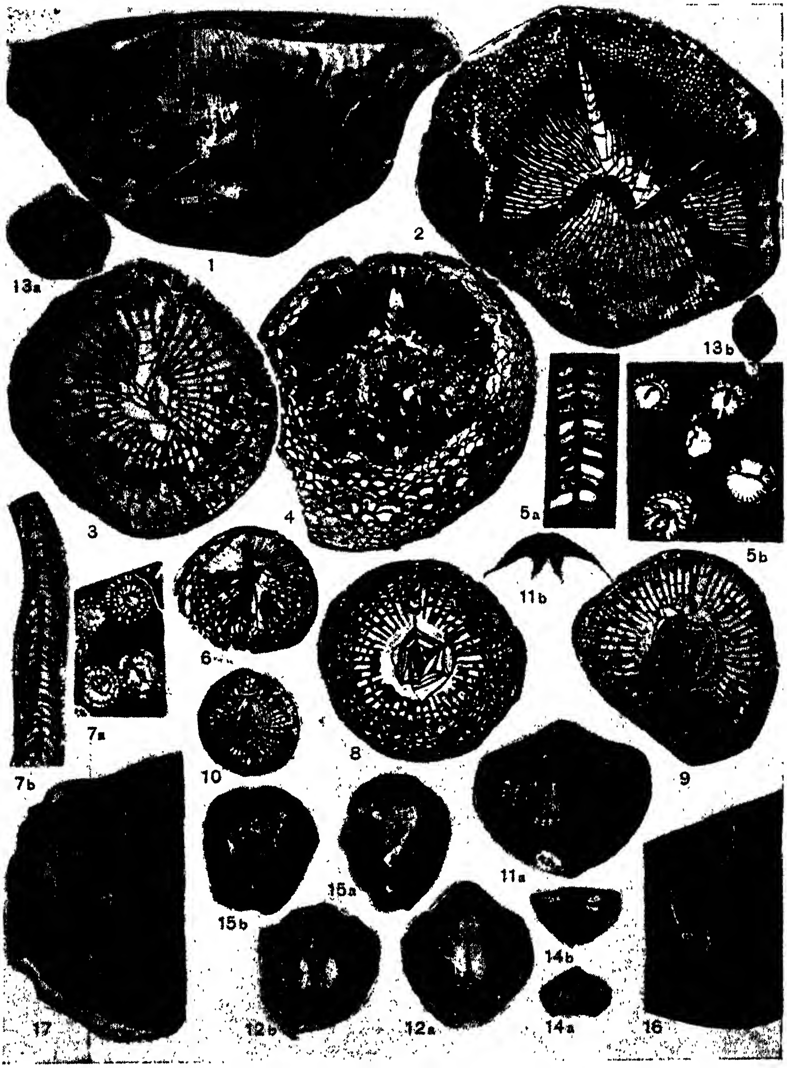

FIG. 36. LOWER CARBONIFEROUS FOSSILS.

grading up towards the old land, Palæocathaysia, that lay beyond the present coastal belt, including Fukien and Kuangtung. All along the Lower and Middle Yangtze Valley there was a belt of low land which extended far into the south-west. And in the south-western area local basins might have held residual Devonian waters.

Thanks to the recent researches carried out in these then depressed areas we can now trace the movements of the Lower Carboniferous sea. The early Carboniferous transgression began from the south-west. Thus in Kweichow there was deposited the Kolaoho Limestone, a rather uniform limestone with intercalated shales, less than 450 m. thick, yielding the characteristic coral, *Cystophrentis*. Traced north-eastward, this limestone is gradually replaced by the lower part of the Mengkungao Series in south-western and central Hunan, consisting of sandstones, shales and intercalated

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EXPLANATION OF FIG. 36.

1. *Productus* (*Striatifera*) *maximus* McCoy. Visean, Kansu. × ⅔.
2. *Kueichouphyllum sinensis* Yü. Lower part of the Shangssu Limestone, Visean, Kweichow. × 1.
3. *Yuanophyllum kansuense* Yü. Chouniukou Formation, Visean, Kansu. × 1⅓.
4. *Pseudouralinia gigantea* Yü. Tangpakou Series, lower part of the Lower Carboniferous, Kweichow. × ⅔.
5 a, b. *Thysanophyllum asiaticum* Yü. a, longitudinal section, × 1⅓. b, transverse sections, × ⅔. Chiussu Series, Kweichow.
6. *Cystophrentis kolaohoensis* Yü. Mengkungao Series, Hunan. × 1⅓.
7 a, b. *Lithostrotion* (*Siphonodendron*) *irregulare* PHILLIPS. Hochou Limestone, Anhui. × 2.
8. *Arachnolasma sinense* YABE and HAYASAKA. Shangssu Limestone, Visean (*Yuanophyllum* zone), Kweichow. × 1⅓.
9. *Clisaxophyllum vesiculosum* Yü. Shangssu Limestone, *Yuanophyllum* zone, Kweichow. × 1⅓.
10. *Dibunophyllum bristolense* GARWOOD and GOODYEAR var. *kankouense* Yü. *Yuanophyllum* zone, Chouniukou Formation, Kansu. × 1.
11 a, b. *Eochoristites neipentaiensis* CHU. Kinling Limestone, near Nanking. a, general view of the two valves in position; b, section of the pedicle valve showing two strong apical plates. × ⅔.
12 a, b. *Martiniella chinglungensis* CHU. a, external view of the pedicle valve; b, a mould of the same showing apical plates and other internal structures. Kinling Limestone, near Nanking. × ⅔.
13 a, b. *Athyris submembranacea* GR. var. *nucleospiroides* CHU. Kinling Limestone. × ⅔.
14 a, b. *Camarotœchia kinlingensis* GR. Kinling Limestone. a, × ⅔; b, × 1⅓.
15 a, b. *Productus kinlingensis* CHU. Kinling Limestone. × ⅔.
16. *Syringopora ramulosa* GOLDF. Longitudinal sections, Kweichow. × 2.
17. *Lepidodendron mirabile* (NATHORST) GOTHAN. Upper part of the Wutung Sandstone, Lungtan, near Nanking. × ⅔.

limestones. The Kolaoho Limestone of Kweichow is overlain by the Tangpakou Sandstone, which is also developed in Kuangsi. But in central Hunan it is replaced by the upper part of the Mengkungao Series, a dark-grey limestone, about 160 m. thick. Further north-east, this limestone extends into the Lower Yangtze Valley where it is known as the Kinling Limestone, but its thickness is reduced to only 10 m. or less. *Pseudouralinia* is the characteristic fossil of this stage.

In the Lower Yangtze Valley the Kinling Limestone, wherever developed, is underlain by a sandy shale which is quickly succeeded downwards by the Wutung Sandstone. The latter formation contains *Lepidodendron mirabile,* a fossil plant so far only known elsewhere in the Culm Measures of Spitzbergen. Thus it is quite clear that the Tournaisian sea advanced steadily towards the north-east. When the body of water moved far into the Lower Yangtze region, shoaling of water was felt in the south-west; as a consequence, the Tangpakou Sandstone was deposited.

The fauna in these deposits exhibits a certain degree of affinity with the Upper Devonian, especially in the small brachiopods such as *Camarotoechia, Composita* and *Athyris,* but is distinct on account of the appearance of a whole set of forms characteristic of the Lower Carboniferous. Among them are: *Neoproductella, Productus, Schellwienella, Eochoristites, Martinella, Syringopora* of the type of *S. ramulosa, Michelinia, Cystophrentis,* and other corals. The well-known Tournaisian *Spirifer, S. tornacensis,* has, however, never been found in this fauna.

The Pseudouralinia stage was succeeded by a temporary withdrawal of water resulting in the deposition of the Chiussu Sandstone (about 237 m. thick) with *Thysanophyllum* in Kweichow, and the Kaolishan Shale, a continental deposit, in the Lower Yangtze Province. In northern Kuangsi and central Hunan, however, normal marine sedimentation went on; and the Ssumen and Shihtengtze Limestones, each some 110 to 150 m. thick, were formed. In these limestones we see, besides *Thysanophyllum,* the first appearance of large *Producti* of the type of *P.* (*Gigantella*) *giganteus*. *Syringopora* also abounds. Finally this inland water disappeared, resulting in the deposition of the Tseishui or Tzemen coal-bearing series in central and south-western Hunan and north-eastern Kuangsi. Then came the extensive flood marking the last stage of the Visean Epoch. It is during this time that Yunnan, Kweichow, Kuangsi, Hunan, the Lower Yangtze region and parts of Kansu were inundated.

The sea was peopled by a flourishing fauna in which many cosmopolitan forms occur. *Gigantella edelburgensis, Productus semireticulatus, Schellwienella crenistria, Dibunophyllum, Kueichouphyllum* and *Yuanophyllum* are among the most common fossils. The last-named genus is perhaps the most characteristic of all. This stage is represented in Kweichow and Kuangsi by the Shangssu Limestone, though in Kuangsi the limestone is sometimes impure and thin; in Hunan by the Tzemenchiao Limestone, 120-150 m. thick; in the Lower Yangtze region by the Hochou Limestone, which is also thin and often shaly; in the western Tsinling geosyncline by the Lioyang Limestone; and in Kansu by the Chouniukou Series.

By means of characteristic corals C. C. Yu divides the Chinese Lower Carboniferous, or the Fengninian system, into four zones as follows in descending order:—

Shangssuan	Zone with *Yuanophyllum*.
Chiussuan	Zone with *Thysanophyllum*.
Kolaohoan	Zone with *Pseudouralinia*. Zone with *Cystophrentis*.

The distribution of these zones is diagrammatically indicated in *Fig*. 37.

In the Chinese basin we have seen that the early Lower Carboniferous or Tournaisian sea was all the time shifting northward during that epoch. This sea was probably in indirect connection with the central Asiatic, Armenian and European waters. The presence of *Daviesiella* indicates that connection. In Europe, the same tendency of movement of marine waters is also noticeable. Thus in the Moscow region the lower part of the Dinantian is represented mostly by clastic sediments, but higher up in the sequence marine facies become more important. In the British Isles the evidence is even more convincing. The detailed zonal work has brought out the fact that from the later part of the Tournaisian epoch to the early part of the Visean the "sea of the northern province" underwent a continual expansion, whereas the "sea of the south-western province" experienced a continual contraction. At the end of the Visean epoch the strandline shifted decidedly to the south.

In North America evidence for the expansion of the northern sea during the early Lower Carboniferous or Waverlyan times is also fairly conclusive. The development

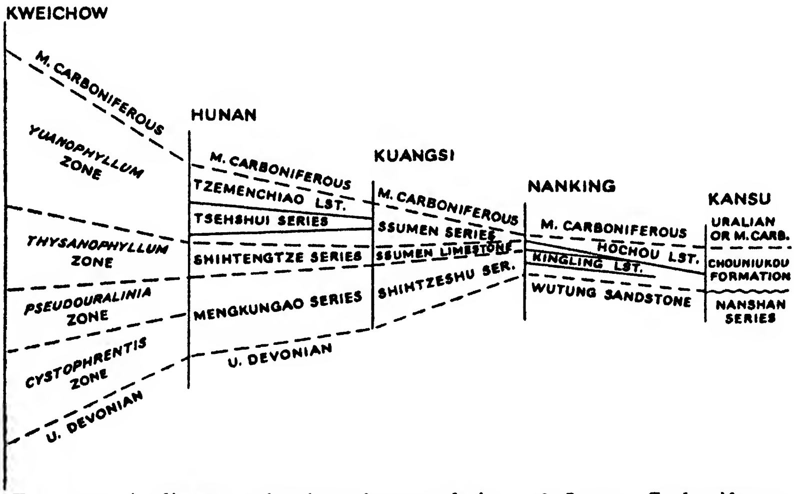

FIG. 37. A diagram showing the correlation of Lower Carboniferous formations in different parts of China. (After C. C. Yü.)

of the Madison Limestone in the Rocky Mountains and the successive overlapping of the Kinderhook, Burlington, Keokuk, and even some of the higher beds in the Mississippi Valley are an eloquent expression of that effect. The fact of interest is that this Mississippian sea swept the interior of North America and then moved northward, as did the early Lower Carboniferous sea in China. The northern sea came back in full swing towards the end of Lower Carboniferous times. This constitutes the Visean transgression in the Eurasian continent and the St. Louis transgression in North America. Large areas in Europe, North Africa, central

Asia, Mongolia and North America were submerged. The sea that covered China at that time was undoubtedly in free communication with the waters of northern India and central Asia. Thus we are enabled to trace the movement of the epi-continental waters in the Northern Hemisphere during Lower Carboniferous times. It was directed at first towards the north and then towards the south. The southern elevation of sea surface was brought to an end by an earth-movement which is known in China as the Huainanian movement.

Huainanian Movement

While so far we have failed to find any angular contact between the Lower and Middle Carboniferous formations in China, there is strong evidence to show that an earth-movement of some importance took place in post-Visean and pre-Moscovian time. It is true that the Visean formation is often apparently succeeded concordantly by the Moscovian. But careful examination of the two series of strata always reveals a break of life-sequence. Sometimes the contact is clearly marked by an irregular erosion surface with a layer of basal conglomerate resting upon it; and sometimes the Moscovian comes into contact with the Visean at one locality, but with older strata, for instance the Wutung formation or its equivalent, in another locality situated near by. Such conditions are frequently met with in the Lower Yangtze region and in both flanks of the middle Nanling. Moreover, the distribution of the Moscovian does not always follow the Visean basins. These facts seem to be clear enough to indicate a widespread, though rather broad, movement, termed the Huainanian, corresponding to the Sudetic folding of Europe.

Moscovian Transgression

The Middle Carboniferous strata are far more extensively distributed in China than the Visean. It will be remembered that the North China massif obstinately stood above the water since the close of Ordovician times. But that area was brought under a shallow and fluctuating

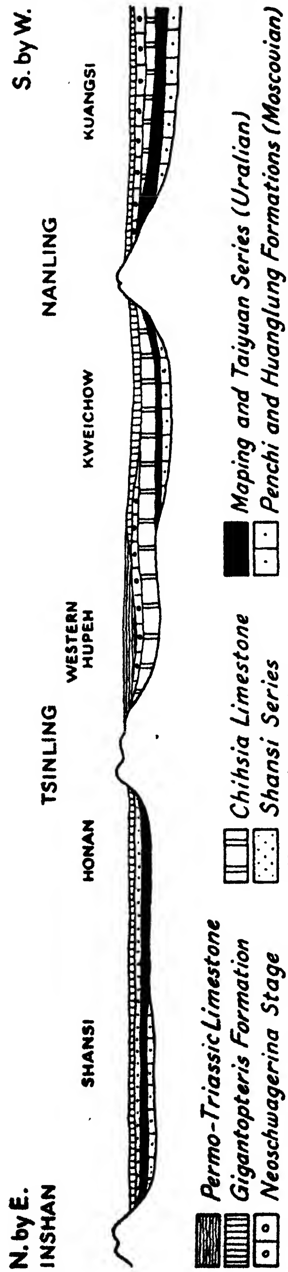

FIG. 38. A generalized section of the Middle Carboniferous-Permian formations.

sea through the Moscovian inundation. The Middle Carboniferous formation in that area comprises shales, sandstones with occasional thin beds of coal, and limestones, known collectively as the Penchi Series. These rocks generally rest on an eroded surface of the Ordovician limestone without noticeable discordance, and are overlain by the Uralian or Lower Permian beds.

Besides the characteristic marine organisms, especially the fusulinids, which occur in the limestone layers, we find a typical Westphalian flora in the shales. *Neuropteris giganteus* is among the most characteristic species. Another peculiar form, *Palæoweichselia,* hitherto only known in the Saar Basin, has been identified by H. C. Sze in the material collected from Kansu.

In southern China the Middle Carboniferous is represented by a pure white or pinkish, fine-textured limestone, named the Huanglung Limestone. It attains a thickness of 100-150 m. in the Huaiyin Hills and the Lower Yangtze region; about 70 m. in eastern Hupeh and central Hunan; and 145 m. in Kweichow; but in central Kuangsi its thickness increases to more than 200 m. Thence the same formation extends into eastern Yunnan and Indo-China. The nature of the rock is essentially the same.

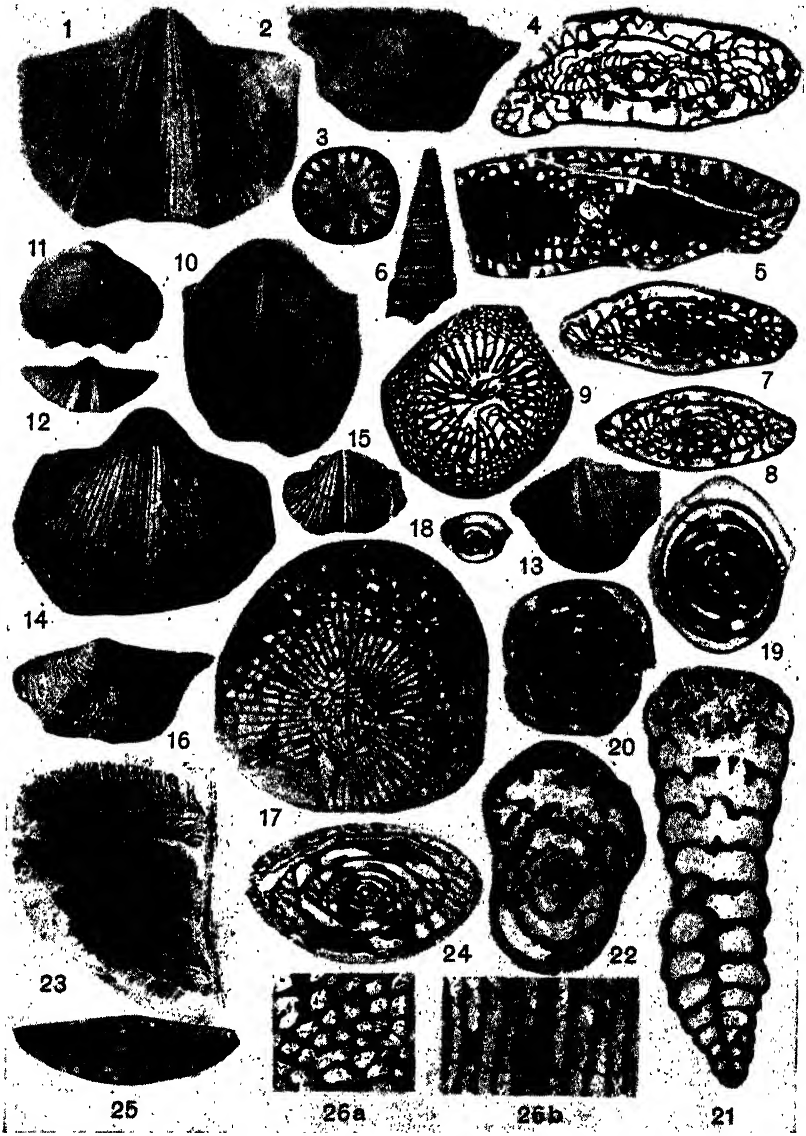

FIG. 39. MIDDLE CARBONIFEROUS AND URALIAN FOSSILS.

EXPLANATION OF FIG. 39.

1. *Spirifer taiyuanensis* CHAO. Taiyuan Series. × $\frac{2}{3}$.
2. *Productus taiyuanfuensis* GR. Taiyuan Series, northern Honan. × $\frac{2}{3}$.
3. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* GR. Taiyuan Series. × $1\frac{1}{3}$.
4. *Pseudofusulina alpina* (SCHELLW.). Taiyuan Series and Maping Limestone. × 10.
5. *Quasifusulina longissima* (MÖLLER). Taiyuan Series and Chuanshan Limestone. × 10.
6. *Solenospira amœna* (DE KON.). Penchi Series, Kansu. × 2.
7. *Triticites parvulus* (SCHELLW.). Chuanshan Limestone, Chekiang. × 10.
8. *Triticites simplex* (SCHELLW.). Taiyuan Series and Chuanshan Limestone. × 10.
9. *Caninia kueihsienensis* YÜ. Maping Limestone. × $1\frac{1}{3}$.
10. *Choristites mosquensis* FISCHER. Changchiakou Limestone, western Shansi. × $\frac{2}{3}$.
11. *Enteletes lamarcki* FISCHER. Yanghukou Limestone, Kansu. × $\frac{2}{3}$.
12. *Spirifer strangwaysi* VERNEUIL. Penchi Series. × $\frac{2}{3}$.
13. *Spirifer fasciger* KEYSERLING. Taiyuan Series. × $\frac{2}{3}$.
14. *Choristites weiningensis* (GR.) CHAO. Weining Limestone, Middle Carboniferous, Kweichow. × $\frac{2}{3}$.
15. *Munella sowerbyi* FISCHER. Yanghukou Formation, Middle Carboniferous, Kansu. × $\frac{2}{3}$.
16. *Productus gruenewaldti* KROTOW. Yanghukou Formation, Kansu. × $\frac{2}{3}$.
17. *Dibunophyllum chui* YÜ. Huanglung Limestone, Kuangsi. × $1\frac{1}{3}$.
18. *Schubertella obscura* LEE and CHEN. Huanglung Limestone. × 20.
19. *Staffella ozawai* LEE and CHEN. Upper part of the Huanglung Limestone. × 20.
20. *Staffella sphæroidea* (MÖLLER). Penchi Series and Huanglung Limestone. × 20.
21. *Cribrostomum longissimoides* LEE and CHEN. Huanglung Limestone. × $16\frac{2}{3}$.
22. *Bradyina nautiliformis* MÖLLER. Penchi and Huanglung Formations. × 10.
23. "*Palæoweichselia*" *yuani* SZE. Probably Penchi Series, Kansu. × 2.
24. *Fusulinella bocki* MÖLLER. Penchi Series and Huanglung Limestone. × 10.
25. *Fusulina cylindrica* FISCHER. Penchi Series, Kansu. × 10.
26 a, b. *Chætetes lungtanensis* LEE and CHU. a, transverse section; b, longitudinal section. Huanglung Limestone, Middle Carboniferous. × $5\frac{1}{3}$.

The fauna in this Middle Carboniferous formation is either identical with, or modified from, the Moscovian fauna of Russia. Minute and primitive fusulinids together with other foraminifera are abundant in the Huanglung Limestone. The genus *Fusulinella,* of the type of *F. bocki, Fusulina cylindrica* and *Fusulina quasicylindrica* often swarm in the rock. Of corals, *Chætetes* is common. Brachiopods are rather rare, but now and then *Enteletes lamarcki* and *Choristites* of the type of *C. mosquensis* occur.

Extensive search for foraminifera in the Penchi and Huanglung formations has enabled us to establish two zones :—

> The Upper Zone (Mβ) : Characterized by the presence of *Fusulina cylindrica* and *F. quasicylindrica.*
>
> The Lower zone (Mα) : Characterized by the presence of numerous minute fusulinids, but the absence of the above-mentioned species.

The Chinese Moscovian sea was evidently connected with the central Asiatic waters through the Nanshan geosyncline. And the central Asiatic waters were undoubtedly in free communication with the Russian sea; for throughout this area the faunal assemblages so far made known are almost identical. Moscovian transgression is a well-known fact in the Timan Mountains and in the Lower Lena area. In the Urals the marine Moscovian formation overlaps the Bashkirian, which apparently corresponds to the Namurian or Yoredale Series of northern England, and which also overlaps the Lower Carboniferous. These are the typical northern developments of that time. On the other hand marine Moscovian is reported to occur in desert Africa. Through lack of zonal work and detailed correlation we are as yet unable to compare the ages of these northern and southern formations. They are, however, not necessarily contemporaneous. Nevertheless, the Namurian (British Isles) of Hudson and the Bashkirian (Urals) of Semichatov are undoubtedly older than the Chinese Middle Carboniferous.

We have found evidence to show that the marine Moscovian in the Moscow district corresponds, if at all, only to the lower part of the Moscovian formation of the Donetz Basin. In the Donetz Basin the higher Middle Carboniferous marine beds with intercalated shales and sandstones evidently merge into the Uralian, but in the Moscow district the higher horizons are represented by the Tegulifera formation, consisting largely of marls with some conglomerates. In China, too, the Moscovian of the south-western provinces is immediately overlain by limestones of Uralian age. In North America a marine formation, *e.g.* the M'Coy, equivalent to the Moscovian of Eurasia, extends as far south as Texas. These facts would seem to indicate that a southward transgression of the Middle Carboniferous waters took place in the Northern Hemisphere before the Asturian phase of the Variscan movement broke out.

Kunming Movement

At the close of Moscovian times orogenesis broke out in Yunnan and Indo-China. In the latter country the movement is the more intense. Folding and overthrusting are in evidence. Elsewhere in China signs of epeirogenic movement at that time are widely noticed, but no unconformity involving angular contact has ever been observed. This movement has been termed the Kunmingian.

Uralian and Lower Permian Transgressions

The Uralian waters were as extensive as the Moscovian sea, so far as the Chinese region is concerned. But cases are known both in northern and southern China where the Moscovian formation is overlapped by the Uralian. Thus in northern Honan the Taiyuan Series, probably representing the Uralian, rests immediately on the Ordovician limestone. In the Yangtze Valley the Chuanshan Limestone, which represents the Uralian, is usually co-extensive with the Moscovian, but sometimes it lies directly on older formations. The northern Uralian waters were undoubtedly shallow and fluctuating, for the Taiyuan Series essentially consists of sandstones and coal-bearing shales, in which only occasional layers of limestone are intercalated. The

Chuanshan Limestone is only about 40 m. thick in the Lower Yangtze Valley, and diminishes to a few metres in eastern Hupeh; but it increases to more than 200 m. in the south-west, where it is known under the name Maping Limestone. In the Kweichow Plateau this limestone is intercalated with terrigenous material. In all these formations fusulinids abound. *Schwagerina princeps,** *Pseudofusulina alpina, P. prisca* and primitive forms of *Triticites* are particularly flourishing in this stage. The corals, *Caninia* and *Orionastræa,* often occur in certain facies.

The Chuanshan Limestone passes upward sometimes into a dirty bituminous limestone with comparatively advanced fusulinids and numerous *Producti,* and sometimes into a coal-bearing shale which is soon succeeded by the Chihsia Limestone, a dark blue limestone containing irregular bands of flint. This limestone, often more than 200 m. in thickness, is well developed all along the Yangtze Valley and in parts of the South-Eastern Uplands. In the Yangtze Gorge district, where Visean and Moscovian strata are wanting, this formation directly overlies a quartzose sandstone probably belonging to the Wutung Formation of Lower Carboniferous age. The same limestone or its equivalent is extensively distributed in Kweichow, Kuangtung, Kuangsi, Yunnan and Sikang. The leading fossils are *Yangchienia, Nankinella, Eoverbeekina, Parafusulina multiseptata, Tetrapora elegantula, Stylidophyllum, Polythecalis, Productus nankinensis,* and *Lyttonia.*

By this time, northern China became a site for continental deposition. The Shansi or Shihhotze Series of productive measures was then laid down. This series of continental deposits yields a copious flora, which has been described by Schenk and, more recently, by Halle in an excellent memoir. The flora is characterized by the presence of numerous familiar Coal Measures species found in other parts of the world. The occurrence, among others, of *Sphenophyllum thoni, Tæniopteris multinervis* and *Walchia*

*Dunbar and Skinner have recently shown that *Schwagerina* auctt. (non Ehrenberg) can be divided into two genera, namely, *Pseudoschwagerina* and *Paraschwagerina,* and that *Schwagerina* Ehrenberg is practically synonymous with *Pseudofusulina* Dunbar and Skinner. In the present work the term *Schwagerina* is used in the sense equivalent either to that of *Pseudoschwagerina* or to *Paraschwagerina.*

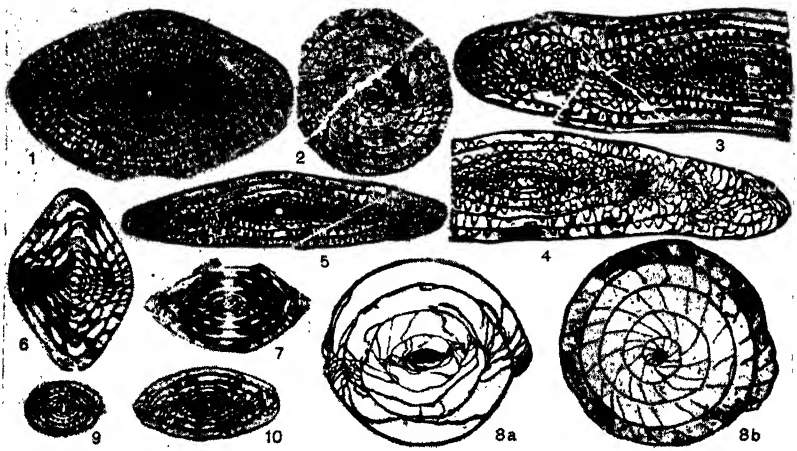

FIG. 40. URALIAN AND PERMIAN FUSULINIDS.

1. *Neoschwagerina craticulifera* (SCHWAGER). Maokou Limestone, uppermost formation of the Lower Permian. × 5.
2. *Verbeekina verbeeki* (GEINITZ). Maokou Limestone. × 5.
3. *Parafusulina undulata* CHEN. Uppermost part of the Chihsia Limestone, Lower Permian, Chekiang. × 5.
4. *Parafusulina multiseptata* (SCHELLW.). Uppermost part of the Chihsia Limestone, Lungtan, near Nanking. × 5.
5. *Pseudofusulina chihsiaensis* (LEE). Upper part of the Chihsia Limestone, southern Anhui. × 5.
6. *Nankinella orbicularia* LEE. Axial section. Chihsia Limestone. × 5.
7. *Yangchienia iniqua* LEE. Lower part of the Chihsia Limestone. × 5.
8 a, b. *Schwagerina princeps* (EHRENB.). Taiyuan Series, Chuanshan and Maping Limestones. a, axial section; b, median section. × 5.
9. *Doliolina claudiæ* DEPRAT. Lower part of the Lower Permian. × 5.
10. *Triticites sinensis* CHEN. Immediately above the Chuanshan Limestone. This form shows a close affinity with a North American fusulinid. × 5.

EXPLANATION OF FIG. 41.

A. *Neuropteris gigantea* STERNBERG. Penchi Series. Slightly enlarged.
B. *Sphenophyllum thoni* MAHR. var. *minor* STERZEL. Upper Shihhotze Series, Central Shansi.
C. *Gigantopteris nicotianæfolia* SCHENK. Restoration drawn by Mrs. Th. EKBLOM, Stockholm, under the direction of T. G. HALLE. × ⅓ approx.
D. *Emplectopteris triangularis* HALLE. A seed-bearing pteridosperm occurring in the Permian of Shansi. The restored plant with attached seeds. × ⅔. (After T. G. HALLE.)

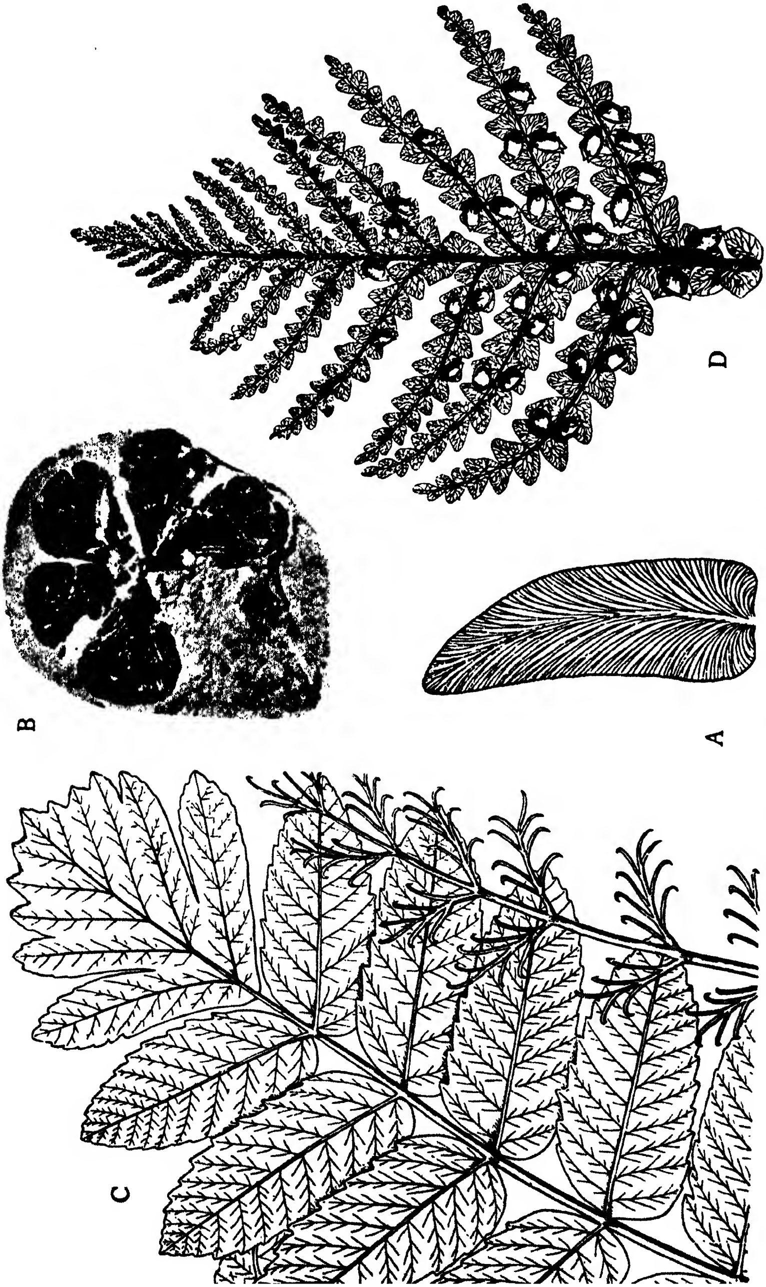

FIG. 41. UPPER PALÆOZOIC PLANTS. *For key see opposite page.*

indicates, however, that we are dealing with the Lower Permian or Autunian. These productive measures are generally overlain by a barren sandstone with shales and clays, or a millstone formation still belonging to the Permian.

The Chihsia Limestone of southern China is overlain sometimes by the Kuhfeng Formation or Paoan Shale, consisting of shaly limestones or shales with abundant impressions of *Glyphioceras* and *Girtyites,* and sometimes by the Maokou Limestone containing exquisite forms of fusulinids, such as *Neoschwagerina, Verbeekina, Doliolina,* and *Sumatrina,* and the corals, *Wentzelella* and *Waagenophyllum.* This limestone is usually absent from the Lower Yangtze Valley, but is well developed in the Central Yangtze Valley and the south-western provinces.

Another massive limestone containing a peculiar sponge, *Amblysiphonella,* is developed in south-western Kuangsi. Its exact stratigraphical position is yet uncertain. Judged from the fact that it occurs in association with the Triassic sandstones in the Upper Sikiang Valley, and that similar sponges occur in the Middle Productus Limestone of the Virgal district in India and in certain Permian limestones (Changhsin Limestone?) in Chekiang Province, it appears probable that this limestone represents a higher stage of the Permian, possibly higher than the Maokou Limestone.

Owing to the presence of abundant fusulinids in these Upper Palæozoic limestones, it has been found possible to divide them into several zones by means of these foraminifera. It must, however, be noted that these animalcules are of gregarious habit. They often occur in such masses as to make up a whole bed or pocket of limestone, but they entirely disappear when traced laterally. Several zonal schemes have been proposed. They must be accepted with caution. The more extensively one examines the vertical and horizontal distribution of various species, the greater becomes the difficulty of separating them into zonal forms. After going through over 6,000 thin sections of material gathered from various parts of China and from different horizons of the limestones, the author has concluded that zonal arrangements cannot yet be satisfactorily established except with regard to the broader divisions. These broad divisions are as follows :—

Lower Permian (*S. stricto*)	Maokou Stage	Zone with	*Doliolina lepida*, *Verbeekina verbeeki*, *Neoschwagerina craticulifera*, and *Sumatrina annae*.
	Chihsia Stage	Zone with	*Parafusulina multiseptata*, *Eoverbeekina*, and *Nankinella*.
		Zone with	*Yangchienia*, *Pseudofusulina gregaria*, *P. tschernyschewi*, *Doliolina claudiæ*, and *Triticites contractus*.
Uralian	Chuanshan Stage	Zone with	*Schwagerina princeps*, *S. fusulinoides*, *Pseudofusulina alpina*, *P. prisca*, and *Triticites simplex*.

In early Uralian times the Chinese sea appears to be largely restricted to the southern part of the country. This sea had some connection with the southern European waters through the Himalayan Geosyncline (upper part of the Lower Productus Limestone) on the one hand and with the central Asiatic and Uralian waters on the other. For the latter connection the passage-way probably lay in the Nanshan Geosyncline, for in Kansu we have found a fauna characteristic of the Chuanshan Limestone of the south. These epi-continental seas periodically shifted northward. Consequently parts of southern China emerged, and a vast arēa in northern China was from time to time submerged, resulting in the formation of the Taiyuan Series. In Wladimir, in the Timan Mountains and in the Ural Geosyncline we find everywhere evidence of the transgressing sea. In this sea the early Permian or Artinskian beds were deposited in the Arctic region. Then the marine waters with a fauna of advanced fusulinids started anew to move southward, drowning large areas in southern China, northern India, Iran* and south-eastern Europe.

Movements of Permian waters over the North American continent seem to be essentially similar to those of the Eurasian waters, so far as the general direction is concerned.

*The writer is indebted to Dr. J. A. Douglas, of Oxford University, for being able to confirm the presence of the Chihsia fauna in Iran.

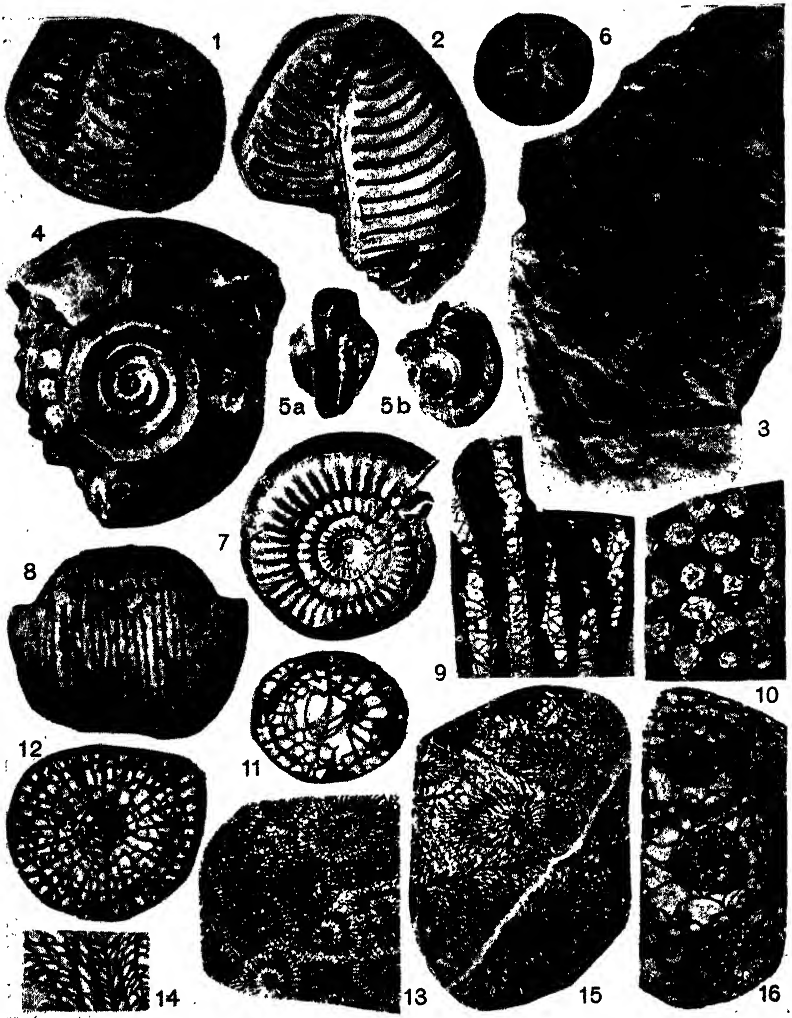

FIG. 42. PERMIAN FOSSILS.

1. *Oldhamina decipiens* (DE KON.). Permian coal-bearing series, Kweichow. $\times \frac{3}{4}$.
2. *Lyttonia nobilis* WAAG. Permian coal-bearing series, Kweichow. $\times \frac{3}{4}$.
3. *Gigantopteris nicotianæfolia* SCHENK. Permian coal measures of southern China and Shihhotze Series of northern China. $\times \frac{2}{3}$.
4. *Gastrioceras kueichowense* YIN. Wangchiapo Limestone, Kweichow. $\times \frac{2}{3}$.
5 a, b. *Anderssonoceras anfuense* GR. Fengtien Series, southern Kiangsi. $\times \frac{1}{2}$.

When the sea drowned the southern part of the Eurasian continent of the *Parafusulina multiseptata* stage the southwestern part of the American continent, namely the present Guadalupe Mountains, was brought under fairly deep water. At the same time the Cordilleran sea was contracting, and its pendent, the Kansas Basin, was gradually drained off.

Tungwu Revolution

Quiet sedimentation came to an end at the closing stage of the Maokou formation. Orogenic forces made a grand display. The Tsinling geosyncline was uplifted to form mountain ranges. South of that zone folding and faulting took place on a rather extensive scale, especially in belts of weakness. In Yunnan and Kweichow this tectonic movement was accompanied by volcanic activity. Large sheets of lava poured out in succession. Northern China remained, however, relatively quiet.

The evidence of this movement is often quite clear in the coalfields of the Lower Yangtze region. There, the Chihsia Limestone and its underlying formations are often folded and faulted, but the folds and faults do not affect the overlying coal-bearing series, the Lungtan or Loping formations, of Middle or Upper Permian age. The coal-bearing series is of course also disturbed, but that disturbance is evidently caused by later movements. Careful observations in the Nanking Hills and in southern Anhui have brought out the fact that the Chihsia and pre-Chihsia rocks are

EXPLANATION OF FIG. 42 (*continued*).

6. *Tachylasma lopingense* GR. Loping Series, Kiangsi. × 2¼.
7. *Gastrioceras perornatum* YIN. Wangchiapo Limestone. × ¾.
8. *Productus yangtzeensis* CHAO. Upper Lydianite Bed near Nanking, and the uppermost part of the Middle Wushan Limestone (now simply named the Wushan Limestone). × ¾.
9. *Tetrapora elegantula* YABE and HAYASAKA. Longitudinal section, Chihsia Limestone. × 3.
10. *Tetrapora elegantula* var. *kunghsienensis* HUANG. Transverse section, Chihsia Limestone. × 3.
11. *Corwenia chihsiaensis* YOH. Chihsia Limestone. × 3.
12. *Waagenophyllum indicum* var. *kueichowense* HUANG. Kweichow. × 4½.
13. *Wentzelella timorica* (GERTH). Eastern Yunnan. × ½.
14. *Stylidophyllum gnomeiense* HUANG. Longitudinal section, Chihsia Limestone, S.W. Szechuan. × 3.
15. *Stylidophyllum volzi* (YABE and HAYASAKA). Chihsia Limestone. × 1½.
16. *Polythecalis chinensis* (GIRTY). Yangsing Limestone, S.E. Hupeh. × 3.

locally folded in a direction appreciably different from the strike of the overlying coal measures, although the two sets of superimposed folds generally both run more or less in a north-easterly direction. This Tungwu Movement, as it has been named, corresponds to the Saalian folding of Stille. It marked the climax of the Variscan or Hercynian movements in the Far East.

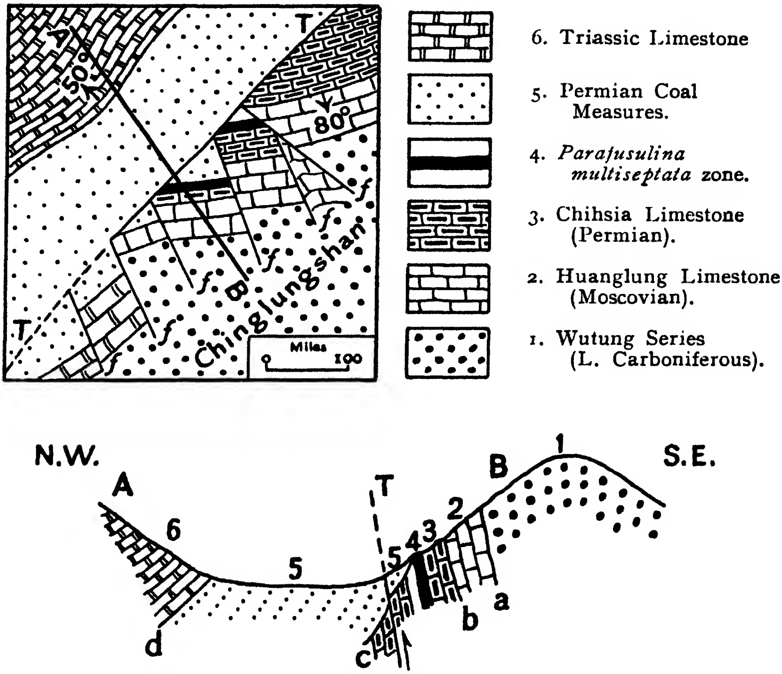

FIG. 43. Geological map and section of the Chinglungshan, south-east of Nanking, showing the unconformity (c) between the Lower and Upper Permian, and "breaks" between the Lower and Middle Carboniferous (a), the Middle Carboniferous and Lower Permian (b), and the Permian and Triassic (d).

MIDDLE AND UPPER PERMIAN TRANSGRESSIONS

As a result of the Tungwu Revolution many large and small basins came into existence in southern China, in which were deposited shales, sandstones and coal seams. Most of the valuable coalfields in southern China were formed during this time. Northern China as a whole stood above water. Mongolia was, however, temporarily submerged, with the consequent invasion of the Loping fauna (see below) largely of the southern type. The southern Permian coal-bearing series is characterized by the presence of the *Gigantopteris* flora (*Fig.* 41). In the northern Permian formation *Gigantopteris* also occurs. But there it seems to appear at a slightly higher horizon than the principal productive measures. The southern facies also differs from its northern equivalent in that the former often contains thin beds of limestone in which the well-known Loping fauna abounds. Besides numerous *Producti, Lyttonia richthofeni, Richthofenia laurentiana, Reticularia inæquilateralis* and *Orthotetes tingi* are characteristic of the Loping Stage.

The Loping Formation passes upward into a thin-bedded limestone, here and there interstratified with sandstones and shales. The limestone facies is known in the middle and lower Yangtze Valley as the Peishan, Tayeh and Chinglung Limestones. It attains a thickness of more than 1,200 m. in Kweichow. In places, the limestone facies is entirely replaced by sandstones and shales, which yield plants, including *Gigantopteris,* and late Permian shells such as *Pseudomonotis, Pecten, Aviculopecten, Modiola, Beyrichia, Leda, Nucula, Pleurophorus, Schizodus, Astarte, Edmondia* and *Bellerophon.* With these long-ranged forms are occasionally associated trilobites belonging to the genus *Phillipsia.* The whole fauna therefore still exhibits a Palæozoic aspect. The fresh or shallow water facies of the uppermost Permian formation is represented by the Luipakou Formation of eastern Hunan and the Hukou Shale of southern Fukien.

In many sections this uppermost Permian formation, sometimes named the Yehlang Stage, appears to merge into the Lower Triassic limestone of similar lithological character without any detectable break. But in the Changhsin coalfield, north-western Chekiang, the Permian coal-bearing series is overlain by the Changhsin Limestone, some 20 m. thick, yielding *Oldhamina.* The latter limestone is in turn overlain by the Triassic limestone. Field evidence seems to point to the existence of an unconformity between the Trias and the Changhsin Limestone, for the Trias is reported to be in direct contact with a number of older formations in the Changhsin coalfield.

Faunal evidence is too meagre to allow any positive interpretation as to the connection of this Chinese Permian sea with other epi-continental waters in Eurasia. If the *Amblysiphonella* belongs to this stage, then this late Permian sea must have covered parts of southern China as well as the Himalayan Geosyncline. The presence of *Oldhamina*-like forms in the Urals also suggests that this inland sea was more or less in direct communication with the boreal waters.

More important is the fact that during Lower Permian times, when southern China and the Himalayan Geosyncline were under rather deep water, north-western Europe was a land area, but when, in the next stage, southern China was turned into low-lying land, the Zechstein sea covered a large area of north-western Europe. The last marine invasion in south-eastern Asia is echoed in southern Europe by that diminutive inland sea in which flourished the *Bellerophon* fauna. At this stage occurred the last phase of the Variscan movement, termed by Stille the Pfaelzian, corresponding to the Suwanian in Chinese geology.

Triassic Transgression

Mention has already been made of a thin-bedded limestone overlying the Permian coal-bearing series in southern China. This limestone, up to several hundreds of metres thick, is partly Permian and partly Triassic. No well-defined boundary between the two has yet been found. It is collectively known as the Chinglung Limestone in the Lower Yangtze Valley, the Tayeh Limestone in the Middle Yangtze province, and the Paomongchung (petroliferous) Limestone in central Kweichow. This petroleum-bearing formation is especially well-developed in the district between Kweiyang and Lunglih. It is thought, however, that the petroleum found in the Paomongchung Limestone is not indigenous. In several places this limestone is replaced, in its basal part, by a dark purple shale which contains *Pseudomonotis* aff. *griesbachi;* but in other places the

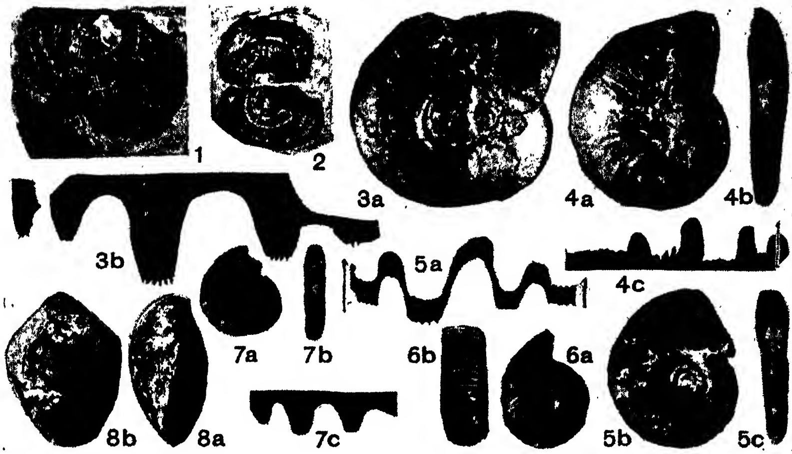

FIG. 44. TRIASSIC AND QUESTIONABLY JURASSIC MARINE FOSSILS.

1. *Halobia comatoides* YIN. Ladinian marl, Omeishan, S.W. Szechuan. $\times \frac{2}{3}$.
2. *Posidonomya* aff. *wengensis* WISSMANN. Ladinian marl, Omeishan, S.W. Szechuan. $\times$ 2.

3 a, b. *Ophiceras sinensis* TIEN. a, internal mould showing the suture, $\times \frac{2}{3}$; b, suture, $\times 2\frac{2}{3}$. Paomongchung Limestone, Central Kweichow.

4 a, b, c. *Clypeoceras* (*Aspidites*) *vidarbhi* var. *falciplicatum* TIEN. a, lateral view, $\times \frac{2}{3}$; b, frontal view, $\times \frac{2}{3}$; c, suture, $\times$ 2. Meekoceras Formation, Kweichow.

5 a, b, c. *Meekoceras* cf. *jolinkense* KRAFFT. Meekoceras Formation, Lower Triassic, Lipo, Kweichow. a, lateral view, $\times \frac{2}{3}$; b, frontal view, $\times \frac{2}{3}$; c, suture, $\times$ 2.

6 a, b. *Kashmirites obliquecostata* TIEN. Tayeh Limestone, Central Hupeh. $\times \frac{2}{3}$.

7 a, b, c. *Xenodiscus* cf. *rigidus* DIENER. Meekoceras Formation, Central Kweichow. a and b, $\times \frac{2}{3}$; c, suture, $\times 3\frac{1}{3}$.

8 a, b. *Terebratula* sp. Sanchiao, Kweiyanghsien, Kweichow. Lower Jurassic? $\times \frac{2}{3}$.

purple shale is absent, and the limestone is impure, often bituminous, yielding abundant Lower Triassic fossils. Among them, *Myophoria, Ophiceras, Clypeoceras* (=*Aspidites*), *Meekoceras, Xenodiscus* and *Sibirites* are the most characteristic.

In the Red Basin of Szechuan the Feisienkuan Series apparently merges into the overlying Chialing Dolomite, in which occur beds of rock salt. The latter formation attains a maximum thickness of 650 m. In places, it is intercalated with marls and sandstones, being occasionally marked by foot-prints. The more persistent facies is named by Chao the Chaohua Limestone. A similar limestone with *Xenodiscus* and *Lecanites* extends as far north as the South Kokonor Range, where it rests, apparently conformably, upon the uppermost Permian. But in the Sikang area only a somewhat metamorphosed greenish shale can possibly belong to the Trias. This formation is only locally developed, and attains a thickness varying from a few scores of metres to several hundreds. Typical Middle Triassic forms, such as *Entrochus liliiformis,* were collected by Loczy from northern Yunnan. A Muschelkalk fauna obtained from Kweichow was described by Koken. More recently J. Fromaget collected *Tirolites* and *Dinarites* from eastern Yunnan. These, according to Patt, show some affinity with the Middle Triassic fauna of south-eastern Europe. The succession and extension of the formation containing these faunas are, however, yet unknown. It does not seem to embody any great thickness of marine sediments. In the Omeishan area, the Middle Trias is represented by a marl containing a fauna of *Halobia* and *Posidonomya,* which, according to T. H. Yin, belongs to the Ladinian Stage.

Thus in Lower and Middle Triassic times southwestern China was under the cover of marine waters which deepened in the Red Basin of Szechuan, and extended eastward along the Yangtze Valley. This sea, however, never encroached upon the South-Eastern Uplands, for in that old land-mass the Trias is usually absent. Only in the southern part of the South-Eastern Uplands do we find plant-bearing shales attributable to the Triassic. The Upper Triassic formation, when developed in southern China, is nearly always of continental origin.

The Triassic formations of northern China are all continental deposits, very often barren of fossils. East of the Ussuri region, north-eastern Manchuria, an arm of the Arctic Triassic sea, however, stretched down from the Lower Lena and Verkhoiansk country. This so-called Ussuri Bay probably reached the south-western part of Japan at its maximum expansion. Whether this narrow epi-continental sea was connected with the southern waters by way of the present Yellow Sea is yet uncertain. At all events, during Lower Triassic or Scythian times large areas in the Arctic were flooded by marine waters. Scales of a ganoid fish belonging to *Boreosomus* are associated with Lower Triassic ammonites in Kweichow. As pointed out by Patt, this genus is so far only known in Spitzbergen outside of China. How these two regions were then linked by a water-way still remains an open question.

The Triassic sea of southern China evidently occupied the Upper Permian basins. It was a more or less residual sea. The remains of life-forms both in the uppermost Permian and the lowest Trias, as well as the nature of the deposits, bear witness to that effect. The southern sea effected, however, an expansion up to the Ladinian Stage in south-western China, and to the Carnian Stage in Indo-China, as it did in central and south-eastern Europe. Parts of the Arctic region were at the same time exposed to subaerial denudation. This is evidenced by the absence of Ladinian in Siberia. Then a powerful tectonic movement took place in eastern Asia, and all the seas in the interior of China finally disappeared. This mighty Upper Triassic movement is particularly pronounced in Indo-China where intense folding and overthrusting characterized the age.

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CHAPTER IV

POST-PALÆOZOIC FORMATIONS AND THE YENSHAN MOVEMENTS

In the late Pre-Cambrian and early Palæozoic periods large areas in China, north and south alike, were repeatedly submerged beneath the sea. With the close of the Ordovician period, northern China was elevated above water and subjected to subaerial denudation for a long time. It was not until Middle and Upper Carboniferous or Lower Permian times that that part of the country was once again flooded by a shallow and fluctuating sea. From then to the present day northern China has remained dry land. But in the southern part of the country marine waters lingered on, with, of course, periodic fluctuations, down to the latter part of the Triassic period. Since that time China has never experienced any marine inundation except in certain districts on the southern coast, *e.g.*, near Hong Kong and in the Lukiang valley, south-western Yunnan. Whether this body of Jurassic water stretched an arm into the Sanchiao district, central Kweichow, is a question which cannot be definitely answered at present. Underneath the North China Plain thin layers of marine Cretaceous or Eocene sediment are possibly present. Of this, we have, however, no positive evidence.

Triassic Continental Deposits

During the Triassic period southern China was still largely covered by an inland sea, which extended into Indo-China and was apparently in communication with Europe through the Himalayan geosyncline. A trough, which grew in depth as time went on, lay on the southern side of the present mid-western Tsinling. In this trough was laid down first, the Feisienkuan Series, purple shales intercalated with limestones, and then the Chialing Dolomite (=Kialing Limestone), with beds of rock salt, estimated at 650 m. in thickness. Early Triassic fossils have been found in the Feisienkuan Series. The Chialing Dolomite contains in places small brachiopods and traces of foraminifera. None of these fossils has afforded positive evidence as to the age of the formation. That it is directly overlain by the Jurassic coal-bearing series renders it, however, highly probable that this dolomite belongs to the Trias. According to Huang, the greater part of the Tapashan is composed of this dolomite. South-eastward, these Triassic rocks give way to a series of shales, sandstones and intercalated limestones constituting the Patung Series. They are apparently overlapped in the Kuichou Basin by the Hsiangchi coal-bearing formation either of Rhætic or Liassic age.

While marine sedimentation was going on in southern China, the vast region of northern China, namely, the area to the north of the Tsinling Range, was largely subjected to peneplanation. But to the east of the Ussuri region an inlet of the sea, representing a part of the Mesocathaysian Geosyncline, came down from the Arctic. Elsewhere in northern China a few basins received terrestrial deposits. In the Western Hills of Peking, a Shuangtsuan Series has been recognized. This series, essentially consisting of purple shales and false-bedded, greenish sandstones, reaches a thickness of several hundreds of feet, and has yielded plants that are believed to be of late Permian or Lower Triassic age. It overlies the Hungmiaoling Sandstone of undoubted Permian age and underlies the Jurassic coal-bearing strata or the Mentoukou Series.

A red arkose sandstone, 900 to 1,000 m. thick, termed the Matou Series, occurs in the western Shansi Plateau, overlying red shales and reddish-green sandstones of the Husung Series. The latter has yielded plants that are believed to be either of Triassic or Upper Permian age. But so far no positive evidence is available to warrant any definite correlation. Again, in the Taning district, south-western Shansi, a fragment of a questionable amphibian

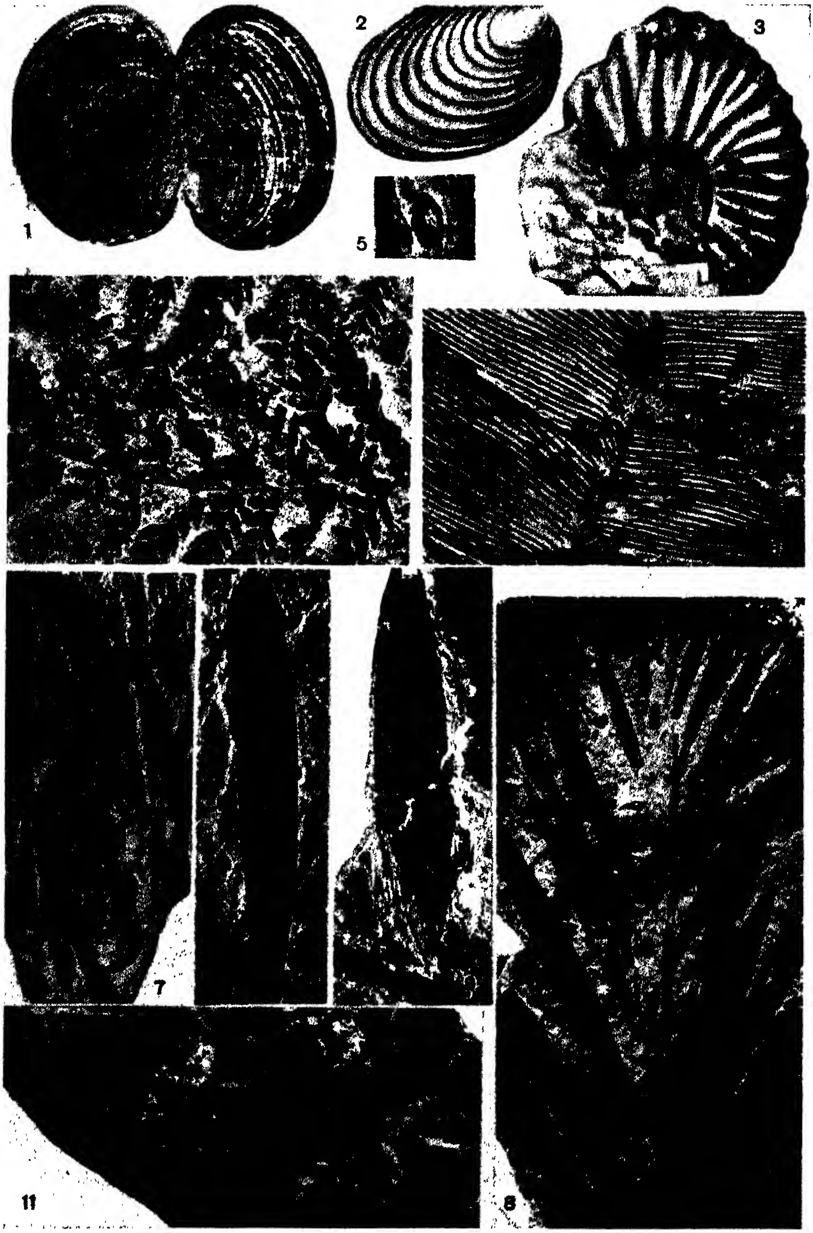

FIG. 45. MESOZOIC FOSSILS.

bone was procured from an "agglomeratic," sandy limestone, which is often intercalated with a sandstone supposed to be of Triassic age. In the northern part of Shensi post-Palæozoic and pre-Jurassic formations spread out over a considerable area. They are divided into two series: the lower, or the Shihchienfeng Series, consisting of dark red sandstones and shales, 600-800 m. thick, which are considered by C. H. Pan to be of Permo-Triassic age; and the upper, or the Yenchang Formation, about 1,000 m. thick, regarded by the same observer as Upper Triassic—Keuper to Rhætic. This latter series consists essentially of grey or greyish-green, cross-bedded sandstones intercalated with a few sandy shales of the same colour. The middle and upper parts of this formation contain petroleum. It also contains thin layers of coal of no workable value.

The great palæogeographical interest of the Yenchang Formation is a well preserved flora collected by C. H. Pan. The plant forms suggest an affinity with the Gondwana flora. *?Schizoneura gondwanensis*, *Danæopsis*, *Thinnfeldia*, *?Nœggerathiopsis*, and *Cladophlebis*, together with *Ginkgo* and *Podozamites lanceolatus*, occur in different horizons of the formation. Hitherto it has been sometimes maintained that the Gondwana flora is quite distinct from the contemporaneous Angara flora, the two floral provinces being

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EXPLANATION OF FIG. 45.

1. *Estheria middendorfi* JONES var. *sinensis* CHI. Wuyi Formation, Lower Cretaceous, northern Fukien. × $4\frac{1}{5}$.
2. *Estheria sinkiangensis* CHI. Upper Jurassic?, Turfan Basin, Sinkiang. × $4\frac{1}{5}$.
3. *Hongkongites hongkongensis* BUCKM. Liassic Shale, near Hong Kong. × $\frac{7}{10}$.
4. *Coniopteris hymenophylloides* (BRONGN.) SEWARD. Lower Jurassic, Fangtze, Shantung. × $\frac{7}{10}$.
5. *Equisetites* cf. *lateralis* (PHILLIPS) MORRIS. Mentoukou Series (Lower Jurassic), Western Hills of Peking. × $\frac{7}{10}$.
6. *Sinoctenis grabauiana* SZE. Jurassic coal-bearing series, Pinghsiang, Kiangsi. × $\frac{7}{10}$.
7. *Baiera* sp. Lower Jurassic, Chihsiashan, near Nanking. × $\frac{7}{10}$.
8. *Podozamites lanceolatus* (L. and H.). Yenchang Series, Shensi. × $\frac{7}{10}$.
9. *Schizoneura gondwanensis* FEISTM. Yenchang Series. × $\frac{7}{10}$.
10. *Nœggerathiopsis hislopsi* BUNBURY. Yenchang Series. × $\frac{7}{10}$.
11. *Danæopsis* (*Pseudodanæopsis*) *hallei* PAN. Yenchang Series. × $\frac{7}{10}$. Note that a detached leaf of this species might easily be mistaken for *Glossopteris*.

separated by the Mediterranean sea of Asia or the Himalayan Geosyncline. Some of these forms suggest that a land bridge across the Asiatic Mediterranean had come into exist-

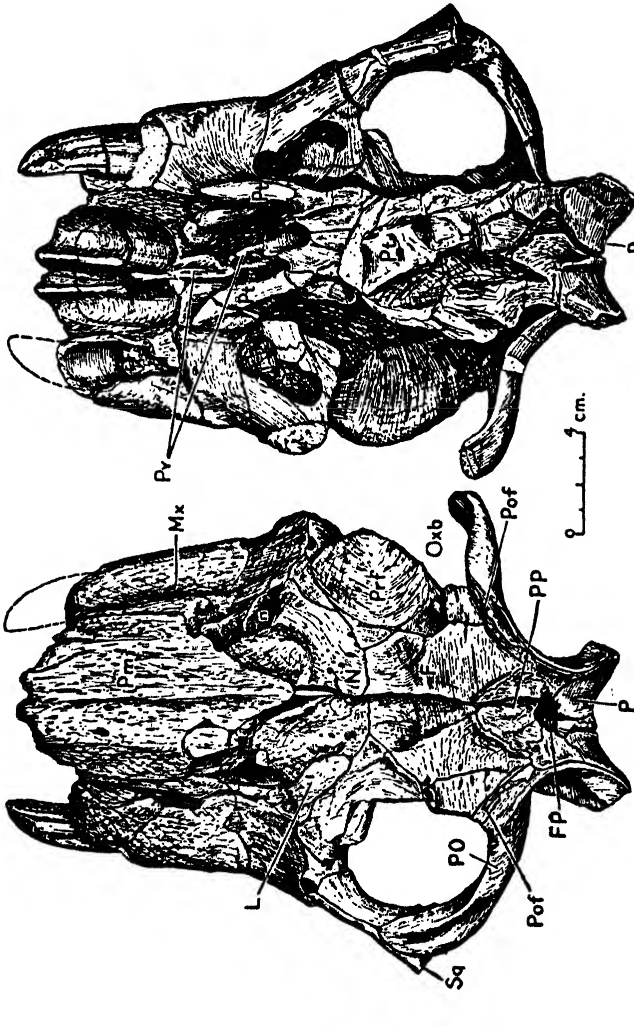

Fig. 46. Skull of *Lystrosaurus murrayi* (Huxley). Left: Top view. Right: Palatal view. Sinkiang. (After P. L. Yuan and C. C. Young.)

ence in the latter part of the Triassic period, if by that time that epicontinental water had not entirely disappeared. Nor is this flora the only evidence for the free land communication between the southern and northern continents. Quite recently Yuan and Young have found in Sinkiang remains of *Dicynodon* and *Lystrosaurus* (*Fig.* 46). These theromorphs must have enjoyed free migration from or to South Africa.

In the western part of Shantung a red or brownish-red sandstone, named the Hsiakunlun Sandstone, is widely developed. This sandstone, attaining a maximum thickness of 700 m., is underlain in the northern and southern parts of western Shantung by a millstone formation, probably of Upper Permian age. But in the central part of the region it directly overlies the Permian coal measures. In the Feihsien district it is overlain by the Mengyin Series of Cretaceous age. The whole formation is often cross-bedded, and occasionally contains conglomerates and shales. Being unfossiliferous, its Triassic age is only inferred from its stratigraphical position and its lithological character.

A series of continental deposits apparently belonging to the Upper Triassic occurs all along the Yangtze Valley. In the Lower Yangtze Valley this series is known as the Huangmaching Formation, having a thickness of about 700 m. The bulk of this formation consists of purple sandstones and shales, with thin coal seams in the basal part, and marly sandstone and a yellowish shale at the top. The purple colour of this series is so striking that it has induced the popular name, Purple Hill, for the Chungshan standing outside the city wall of Nanking, long renowned for its scenic beauty. *Cladophlebis, Tæniopteris, Macrotæniopteris, Dictyophyllum* and *Podozamites lanceolatus* have been found in this formation, but, strange to say, no typical Gondwana floral elements seem to occur as they do in the north.

In the neighbourhood of Mienhsien, western Tsinling, Huang observed a series of sandstones and conglomerates with some greenish-grey shales and poor coal seams, totalling a thickness of no less than 1,000 m. This Mienhsien Series, as it is called, lies in parallel contact with metamorphosed Permian limestone, and is itself highly disturbed and metamorphosed to some extent. The plant remains found in this series are considered by T. G. Halle as not older than

Rhæto-Liassic and not younger than Middle Jurassic. Huang would correlate this series with the Hsiangchi Formation, which is widely exposed in the marginal part of the Red Basin of Szechuan, and which is generally considered to be Lower Jurassic. Until more decisive palæobotanical evidence is available there is no objection against a correlation of this series with the Huangmaching of the Lower Yangtze Valley. It is a remarkable fact that all these Upper Triassic formations are characterized by a prevailing purple colour, north and south alike.

Marine Triassic formations are extensively developed in south-western China, including the Yangtze Valley. These have been dealt with in the last chapter.

Kintzean or Huaiyang Movement

The Shuangtsuan Formation, if it be of Triassic age at all, concordantly overlies, in the Western Hills of Peking, the Hungmiaoling Sandstone of Permian age. There is no detectable discordance between the two series of strata, though a break is likely to exist. Similarly the Yenchang Formation in northern Shensi concordantly succeeds the Shihchienfeng Series. It would thus seem that northern China either remained quiet, or that it was only towards the latter part of the Triassic period that this region was subjected to movements of an epeirogenic nature.

In southern China conditions were different. The Huangmaching Formation in the Huaiyang Range and Nanking Hills usually rests unconformably on the Chinglung Limestone of Triassic age. The basal part of the Huangmaching Formation frequently contains conglomerates with rounded pebbles of the Triassic limestone. Sometimes it regularly succeeds the Chinglung Limestone, but sometimes it comes to rest on the Chihsia Limestone of Lower Permian age. The unconformable contact is clearly shown at the Kintzeshan, south of Siashu, near Nanking.

This Huaiyang Movement, as it has been called, which occurred towards the end of Triassic time, seems to have affected south-eastern Asia generally. The lingering trough to the south of the western Tsinling, in which was deposited

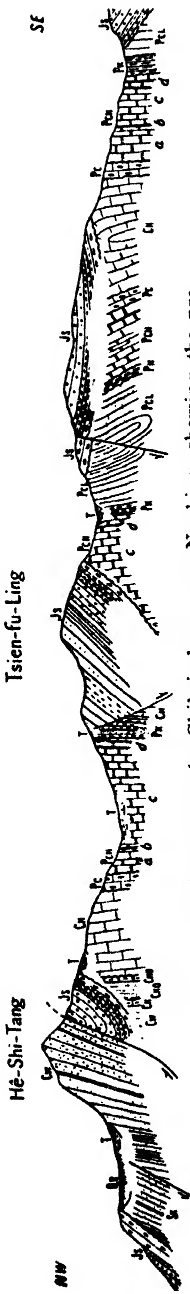

FIG. 47. Section across the Chihsiashan, near Nanking, showing the pre-Jurassic unconformity.

SK, Silurian shale.
CW, L. Carboniferous quartzite.
CK, Kinling limestone (Tournaisian).
CKO, Shales.
CHO, Visean limestone.
CH, Moscovian limestone.
PC, Uralian limestone.
PCH, Chihsia limestone (L. Permian).
PK, Gastrioceras formation (L. Permian).
PCL, Permian coal-bearing series.
JS, Jurassic sandstone.
QR & T, Recent deposits.

the Chialing Dolomite, more than 600 m. thick, was, at least in its northern part, turned into dry land or mountains at this time. Intense folding took place in Indo-China, where the folded Carnian beds are unconformably succeeded only by meagre records of sedimentation assigned to the highest stage of the Triassic.

NANHSIANG MOVEMENT

The Huangmaching Series of Upper Triassic or Rhætic age is unconformably overlain, in the Nanking Hills, by the Jurassic. The unconformable contact is particularly well exposed in the Nanhsiangshan, Chihsiashan, and several other hills to the east of Nanking. In the core of the Nanhsiangshan anticline the Huangmaching Series is in direct contact with highly inclined and eroded beds of the Chihsia Limestone. Resting unconformably on these unconformable formations is a quartzose sandstone with small pebbles, which underlies elsewhere a plant-bearing shale of Liassic age. Unconformable contact of an equally pronounced nature is observable at the base of the Jurassic almost all along the Nanking Hills. The term Nanhsiangian is proposed to denote this post-Rhætic movement.

Elsewhere in China tectonic investigation has not yet been carried out to such detail as to enable us to distinguish these two phases of late Triassic movements from each other. The fact that the Lower Jurassic may come to lie on any formation older than itself throughout China speaks for the widespread nature of the post-Rhætic movement. The Huaiyang and Nanhsiang movements correspond to phases of the Old Cimmerian movement in Europe.

Jurassic Deposits

Jurassic rocks are widely distributed in China. Except for some slightly altered argillaceous sediment which has yielded *Hongkongites*, a Liassic ammonite, in the neighbourhood of Hong Kong, and a thick deposit in the Lukiang valley,* all the Chinese Jurassic formations are continental or fresh-water deposits. They are usually shales, sandstones and conglomerates, containing valuable seams of coal, and occur in large and small basins between mountains or highlands that arose from the post-Palæozoic and late Triassic movements.

Such Jurassic formations are known in the Weihsien and Poshan-Tzuchuan coalfields in Shantung. In the former district the coal-bearing formation is named the Fangtze Series, and yields *Ctenis, Todites, Podozamites, Coniopteris, Asplenium, Baiera* and other familiar Jurassic plants. The exposed thickness of the series amounts to less than 40 m., being overlain by a tuff of unknown age. In the Poshan-Tzuchuan coalfield, the Jurassic formation is represented in the lower part by yellow-green sandstones and dark shales with poor coal seams, having a total thickness of about 160 m., and in the upper part by red sandstones and conglomerates attaining a thickness of 400 m. This series is

*Dr. T. H. Yin and his colleagues on the Geological Survey have recently confirmed the reported occurrence of a thick marine Jurassic formation in the Lukiang valley, Western Yunnan.

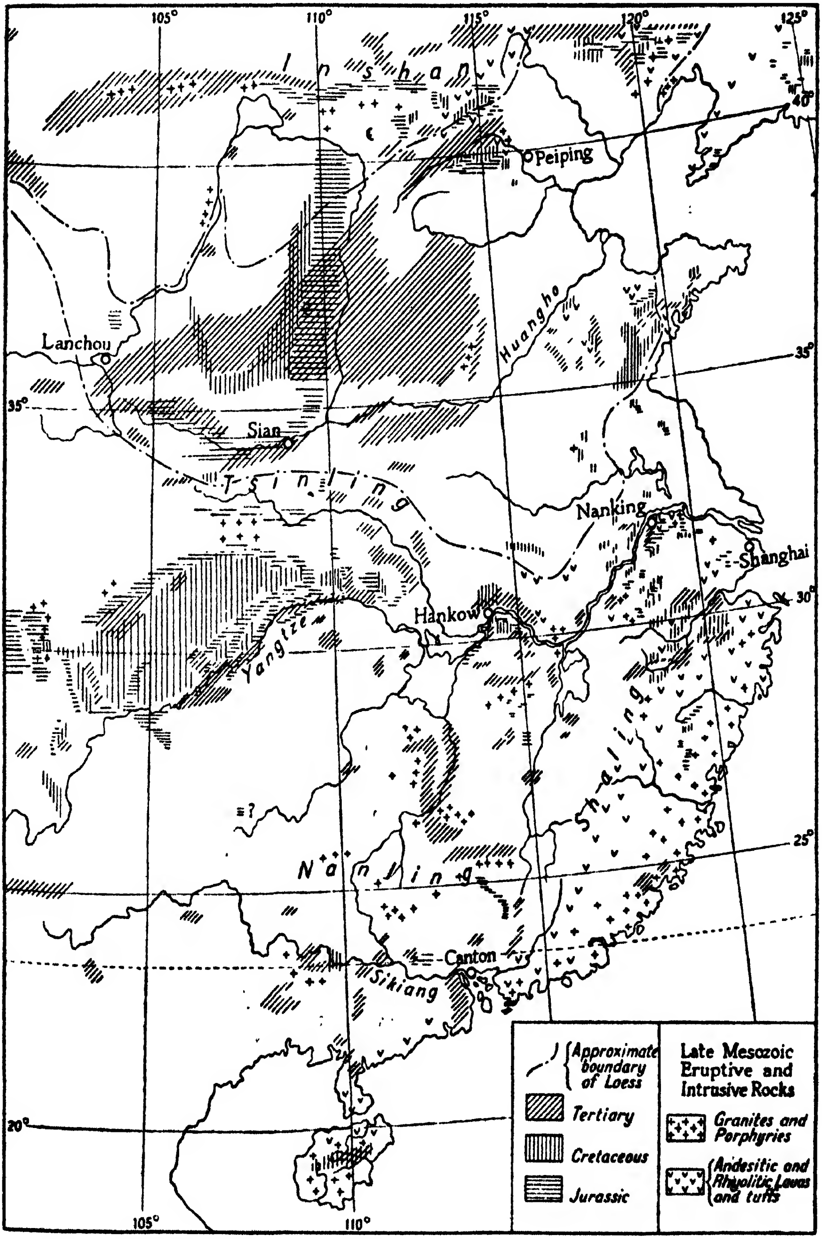

FIG. 48. Map showing the distribution of post-Triassic deposits in China.

concordantly underlain by a dark red sandstone, 680 m. thick, questionably referred to the Trias.

Isolated basins filled up by Jurassic sandstones, shales and conglomerates, usually with some workable coal seams, occur in the region of north-western Hopei, northern Shansi, Suiyuan and the Tachingshan Range. The coalfields of Mentoukou and Chaitang, in the Western Hills of Peking, of Yuhsien, Yangyuan, and Hsuanhua in south-western Chahar, and of Kuangling and Tatung in northern Shansi are among the best known for their valuable Jurassic coal. A copious Angara flora has been furnished by these Jurassic formations. Besides the genera already mentioned in connection with the Shantung deposits, *Pterozamites, Thyrsopteris, Elatides, Hymenopteris, Dicksonia, Czekanowskia, Pterophyllum* and *Taxites* are among those frequently reported. In these coalfields, the coal-bearing shales and sandstones, a few hundred metres thick, usually occur, as in Shantung, in the lower part of the Jurassic; the upper part of the formation generally consists of greenish, buff and red sandstones and massive conglomerates, not infrequently intercalated with igneous material.

In the Mentoukou district, near Peking, the Mentoukou coal-bearing series is, for instance, overlain by the Chiulungshan sandstones and conglomerates, some 600 m. thick, intercalated with sheets of amygdaloidal diabase and beds of tuffaceous sandstone. This series merges upwards into the Tiaochishan Series of shales, 1,500 m. thick, containing lenticular layers of coal, beds of conglomerate and andesitic lava. Formerly it was believed that the Tiaochishan Series was unconformably overlain by the Chiulungshan Series, and that the former was of Jurassic and the latter of Cretaceous age; but careful study in the last few years has encountered much difficulty in drawing the boundary between the two series. Both of them may belong to the Jurassic or to the Lower Cretaceous. The question is still undecided. It must be remembered that the coalfields in question and those allied to them are all distributed in mountain-locked basins. They follow the general trend of the northern Taihang and southern Great Khingan—a fact which seems to suggest that the basins came into existence after a post-Triassic movement which took place in those mountainous areas.

On the western side of the Luliang Range, namely, in north-western Shansi and northern Shensi, the Jurassic deposits evidently belong to a somewhat different facies. There, the Lower Jurassic is represented by the Wayaopo coal-bearing series yielding the usual Jurassic plants, according to Pan. This series consists of grey sandstones with some intercalated shales and coal seams, about 800 m. thick. The Wayaopo Series is followed upward by a red shaly sandstone of the Wutingho Formation of Wang, which is probably equivalent to the Ichuan Conglomerate of Fuller and Clapp. Then comes the Tali Limestone of Wang or the Anting Limestone of Fuller and Clapp. This fresh-water limestone evidently varies considerably in thickness; for Wang gives a thickness of only 20 m., but Fuller and Clapp estimate it at 60 m. The limestone is usually shaly, and it bears fish remains, which, according to the preliminary determination of Smith Woodward, belong to the family Pholadopholidæ, characteristic of the Upper Jurassic of Europe. Towards the west, the formations of Shensi partly extend to the north-west of Lanchou, where their total thickness is reduced to about 200 m., and where they rest upon the Permo-Triassic sandstone.

After the Nanhsiang Movement towards the end of the Triassic period, a vast fresh-water lake evidently came into existence on the western side of the Luliang Range which runs obliquely across the Shansi Plateau. Of course the Shansi Plateau was probably non-existent in those days.

Similarly an even vaster lake was formed on the southern side of the western Tsinling and the western side of the Gorge mountains of the middle Yangtze. This is the present Red Basin of Szechuan. All along the border of this red basin, the Hsiangchi coal-bearing series, believed to be of Liassic age, forms marginal hill ranges and apparently extends into the heart of the basin, where it is buried under a thick covering of continental strata. The Hsiangchi Series consists of yellow and dark-grey sandstones with grey and black shales in which workable seams of bituminous coal occur. The total thickness is estimated at 500 m., somewhat thinner than the Wayaopo Series in the Shensi Basin of the north. This series is overlain with apparent conformity by the Tzuliuching Series of Cretaceous age, which contains fresh-water limestones, as in the case of the Shensi Basin.

On the western side of the Red Basin of Szechuan a coal-bearing Jurassic formation occupies extensive areas in the "Alps of Sino-Tibet." The formation is essentially composed of shales, slates, phyllites, schists, sandstones and quartzites, with thin seams of coal or carbonaceous shales in places. Loczy considered this formation as "Eozoic." Heim, on the other hand, is inclined to regard it as Mesozoic. Tan and Lee found Mesozoic plants in the formation, and attribute it to the Jurassic. The whole series sometimes rests unconformably on Permian marble, and sometimes on a greenish slate of questionable Triassic age. It is often invaded by large and small masses of granite, with a well-developed contact zone as described by Heim. Auriferous quartz-veins, associated with the granitic intrusions, sometimes attain considerable economic importance.

Lower down the Yangtze Valley coal-bearing Jurassic formations similar to the Hsiangchi Series are developed in the Kiayu and Hsienning districts, south-eastern Hupeh, and in the Anyuan, Pinghsiang, Ifeng, Hsingan and Tsungjen districts, central Kiangsi. In the Nanking Hills the Jurassic formation is known as the Hsiangshan Series, which consists of coal-bearing shales in the lower part, and quartzose sandstones often containing small pebbles in the upper part, having a total thickness of about 400 m. It is unconformably underlain by the Huangmaching formation already mentioned, and unconformably overlain by red shales and sandstones and a tuffaceous sandstone believed to be of Cretaceous age.

While the Jurassic is well developed in the Nanking Hills, it appears to be generally absent both from southern Anhui and Chekiang. In northern Fukien, however, the Jurassic coal-bearing series forms important coalfields; and the white, grey and greenish sandstones, with beds of conglomerate and layers of reddish-brown, greenish-grey and black shales, which represent the upper part of the formation, over 1,000 m. thick, build up precipitous mountains particularly dominating in the Shaowu and Nanping districts. The lower part of the formation sometimes rests unconformably upon the Permian limestone and sometimes upon still older rocks.

Isolated outcrops of micaceous and arkose sandstones, conglomerates, and black shales with seams of coal and plant remains, probably of Jurassic age, are known in the North River and West River districts, Kuangtung. They often occur in a highly folded state, and in places are invaded by granite. Detailed knowledge as to their stratigraphical relation is, however, still lacking. Further north in the eastern Nanling Range the Lower Jurassic rests on older strata with a pronounced unconformity. The unconformable contact is best exposed on the boundary between the Yichang district on the Hunan side and the Yuyuan district on the Kuangtung side.

Ningchinian Movement

In the Nanking Hills, especially in the Chihsiashan, a mighty display of orogenic forces in late or post-Jurassic time is recorded by intense folding and overthrusting which do not involve the Kienteh and the tuffaceous series of Cretaceous age, though the latter is also highly disturbed. A tectonic relation of a similar kind, though not always to the same degree, is observable all along the Nanking Hills wherever the Jurassic is present. These arcuate hill-ranges, which stretch between the cities of Nanking and Chinkiang and beyond, were undoubtedly formed, for the first time, by this movement. Hence it is designated as the Ningchinian Movement.

As will be shown in connection with our tectonic discussion, the Nanking Hills form a south-eastern reflex arc of the Huaiyang Arc, and are connected with the Tsinling Range. It would be natural, therefore, to find similar evidence elsewhere in the Tsinling. Such evidence is available. In the Shangcheng and Kushih districts on the northern side of the eastern Tsinling, H. C. Tan found a formation consisting of quartzite, quartzitic conglomerate, slates, dark shales and thin seams of anthracite. From the dark shales *Pityophyllum* cf. *longifolium* was procured, proving the Jurassic age of the formation. These Jurassic beds are in unconformable contact with the ancient crystalline rocks of the Wutai System. The Jurassic strata often stand on end, and are overlain by red-brown tuff, lava and tuffaceous conglomerate with a striking unconformity. The overlying tuffaceous series is rightly correlated by Tan with the tuff-conglomerate of Shantung, where Lower Cretaceous fossils occur.

In the western Tsinling the Jurassic formation or the Mienhsien Series, of which mention has already been made, is intensely folded and metamorphosed. In the Tapashan, which is a south-eastern branch of the western Tsinling, Huang found the Cretaceous conglomerate unconformably overlying the Triassic purple shale. These and other facts led Huang to conclude that intense folding occurred in that part of the Tsinling at the end of the Jurassic. Thus it will be realized that the whole of the Tsinling Range was under powerful compression during the Ningchinian Movement.

The two inland basins—one in the north, the Shensi Basin, and the other in the south, the Red Basin of Szechuan—seem to have remained relatively quiet, and possibly continued to subside in spite of an orogenic display on or near their borders; for in these basins the Jurassic is apparently succeeded by the Cretaceous with conformity. If there is any discordance between them, it is so slight that it is beyond perception.

Nor is the Tsinling zone the only area in which orogenic forces were let loose. Both northern and southern China were likewise affected at the same time, though the intense folding was restricted to certain belts. In the Tachingshan, one of the east-west ranges that form the Inshan tectonic zone standing between northern China and Mongolia, the Jurassic is overfolded and overthrust to the north. Such overfolding and overthrusting can be traced from the north-west of the Ordos region to the Hsuanhua district, south of Kalgan. In the Chimingssu coalfield, near Hsuanhua, the Sinian limestone is thrust upon the Jurassic strata, which are recumbently folded. Disturbance of similar nature is observed in the Chaoyang district on the eastern border of Jehol. The mountains there form the southern prolongation of the Great Khingan.

Compressed folds, sometimes accompanied by thrusts which often involve the Jurassic formation, are met with all along the mountain ranges of north-western Hopei and north-eastern Shansi. They form the north-eastern continuation of the Luliang Range. In these areas the absence of positive evidence for determining the age of the supposed Cretaceous strata renders the exact dating of the movement less certain than in the Tsinling and the Nanking Hills.

Another group of ranges that are believed to be affected by this episode of crustal movement is the Alashan, Yintzeshan, Arbus-ula, and the Kharanarinula, which make an impressive array along the upper Huangho Valley from the south to the north. In these ranges the strata are repeatedly overfolded and overthrust from west to east. The youngest formation involved in the folding is a "supra-Carboniferous" sandstone which Teilhard and Licent are inclined to regard as Mesozoic. If these ranges first came into being earlier than Jurassic time, they were undoubtedly refolded along the old lines of weakness by the post-Jurassic and still later movements; for to the south of these ranges, and roughly in line with them, is the Lungshan Range, in which the Cretaceous forms an anticlinal cover.

Over the vast area of Mongolia, Berkey and Morris observed groups of coarse sediments, thousands of feet thick, which they assign to the "mid-Mesozoic." These formations are distributed widely apart from each other, and are preserved in down-faulted blocks or local basins. The occurrence of poorly preserved plants and their stratigraphical position with reference to formations of known age led Berkey and Morris to consider some of these deposits as Jurassic. They have been folded or otherwise disturbed, and are also invaded by porphyries. On the eroded and levelled surface of this complex series rests the Lower Cretaceous. It

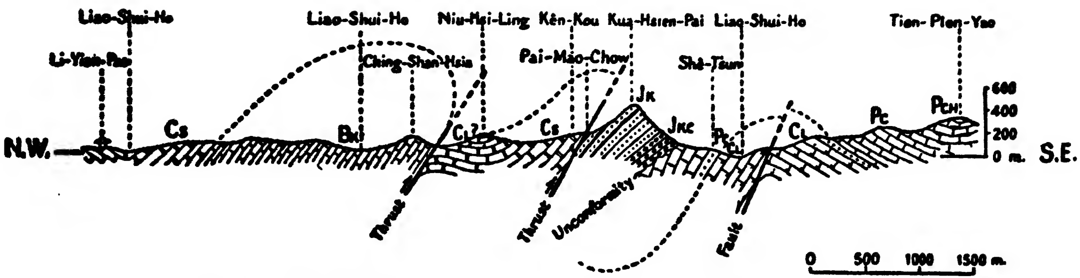

FIG. 49. Section of the Kênkou district, eastern Nanling. (After Y. Y. LEE and S. CHU.)

Dk. Kuhua Limestone (Devonian)	Pc. Chaoshui Limestone } Permian	Jkc. Kênkou Basal Conglomerate } Jurassic
Cl. Shihtzuchu Series } L. Carboniferous	Pch. Chihsia Formation } Permian	Jk. Kênkou Series } Jurassic
Ct. Linwu Series } L. Carboniferous		

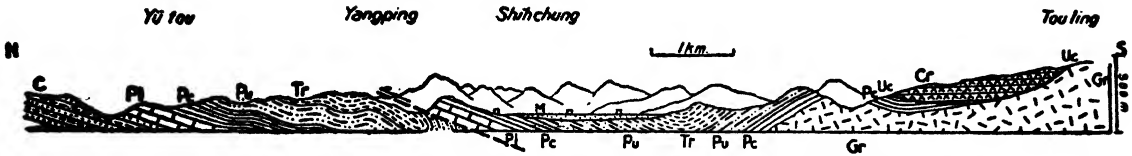

FIG. 50. Section of Shichung, south of Lungyen (south-eastern Fukien), showing the pre-Cretaceous unconformity (UC). (After T. F. HOU and others.)

Pl. Chihsia Limestone } Permian.	C. Nanching Quartzite (Carboniferous).	Cr. Touling Volcanic Rocks (Cretaceous).
Pc. Gigantopteris Coal Series } Permian.	Tr. Yangping Shale (Triassic).	M. Alluvium.
Pu. Tsuipingshan Shale } Permian.	Gr. Granite.	

would thus appear probable that the post-Jurassic movement likewise affected Mongolia.

As to southern China, the folded and eroded Palæozoic formations in Chekiang are unconformably overlain by the Kienteh Series with Cretaceous fossils. That region may have been folded several times before the post-Jurassic movement took place. But the occurrence of the continental Cretaceous strata in well-defined basins would seem necessarily to imply a thorough readjustment of the land surface immediately before it received the Cretaceous deposits.

In the Nanling Range the Jurassic is more or less strongly folded, but the Red Sandstone belonging either to the Upper Cretaceous or early Tertiary usually shows only a gentle inclination. The Jurassic beds in the neighbourhood of Canton and in the Lochang district, northern Kuangtung, are, as pointed out by H. C. Chang, also often highly folded.

Summing up the evidence, it is hardly possible to doubt the intensive and extensive nature of orogenic movements that took place in the latter part of Mesozoic time in China. W. H. Wong has discussed the problem at some length, and proposes to name these movements collectively the Yenshanian. He further distinguished certain phases of this series of movements, and designated them as phases A and B with an intermediate phase in between. Such a collective term is as useful as convenient. But as to the phase-designation, it would be more definite to use some such neutral terms as are proposed here. The Ningchinian phase would seem to correspond to the Yenshanian phase A of Wong and to the Young Cimmerian movement of Stille.

Cretaceous Deposits

Cretaceous formations only occur in China in continental basins. The most extensive group of these basins are those developed in Mongolia. There, the Lower Cretaceous, or the Oshih-Ondaisair Formation, consists of sandstones, often cross-bedded, mudstones and papery shales, and totals a few hundred metres. These rocks have yielded abundant organic remains. The well-known crustacean, ***Estheria middendorfi,*** sometimes occurs in crowds. ***Lycop-***

tera of the type of *L. middendorfi* also abounds. Insects such as *Ephemeropsis, Trichoptera* and *Chironomopsis,* and plants belonging to *Baiera* and *Czekanowskia* occur in the papery shale. The more striking aspect of the fauna is the saurians. Iguanodonts, described by Osborn under the generic names *Protiguanodon* and *Psittacosaurus,* are associated with other herbivorous and carnivorous monsters. These formations are correlated with the Wealden, although Osborn has remarked that some of the sauropods, notably *Asiatosaurus,* bear a close affinity with the Jurassic fauna of Europe.

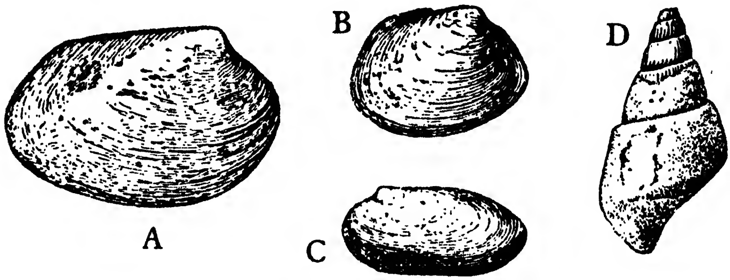

FIG. 51. CRETACEOUS FOSSILS.

A. *Cyrena hupehensis* GR., right valve; Kuichou Series, Lower Cretaceous, western Hupeh.
B. *Corbicula anderssoni* GR., right valve; Lower Cretaceous, Shansi.
C. *Mycetopus mengyinensis* GR., left valve; Kuichou Series, Lower Cretaceous.
D. *Campeloma clavilithiformis* GR., Upper? Cretaceous, Yihsien, South Manchuria.

The Irendabasu and Djadokhta beds represent perhaps the Middle or Upper Cretaceous. It is in these sandstones and shaly strata that the famous dinosaur eggs were found. From the point of view of the evolution of the vertebrates the occurrence of the Protoceratopsians in these higher horizons of the Cretaceous has drawn much attention; for they afford a transitional type between the Jurassic Ornithopods and the true Ceratopsians. This rich fauna, including crocodiles, rather suggests a genial climate toward the end of the Cretaceous period. It is said that these Cretaceous formations shifted their site of deposition as time went on. Exact correlation is therefore impossible. Evidently they did not cover the Mongolian basin (as a whole) to any great extent, even if we allow the possibility that a large part of the Cretaceous deposits has been removed subsequently.

On the southern border of the raised Mongolian basin, namely, to the north of Kalgan, Barbour describes a coarse red conglomerate unconformably overlying the gneiss, and states that it is in turn overlain by a great series of trachytic lavas, tuffs, ashes and local conglomerates and sandstones.

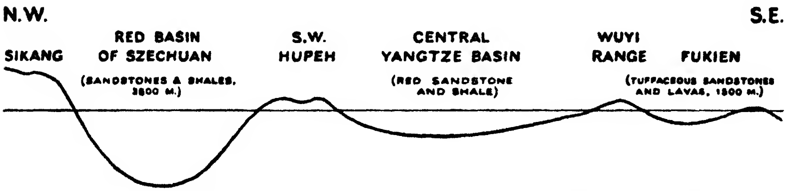

FIG. 52. Cross-section in southern China of the Cretaceous floor at the end of the Cretaceous period.

Barbour tentatively regards this Kalgan Series as late Jurassic or early Cretaceous. The deposition of such pyroclastic material clearly indicates the orogenic effect of the Ningchinian movement along the Inshan zone. This volcanic series was slightly eroded before it became covered by the Nantienmen Conglomerate, some 200 m. thick, typically developed at Hanoorpa, north of Kalgan.

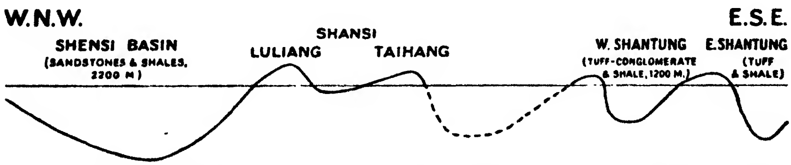

FIG. 53. A section across northern China showing the approximate shape of the Cretaceous floor at the end of the Cretaceous period.

Further south, in the Western Hills of Peking, the Mentoukou Series with Lower Jurassic plants is unconformably overlain by the Chiulungshan Series consisting of conglomerates, tuff and tuffaceous sandstones. This latter series has been generally regarded as Upper Jurassic, without fossil or any other positive evidence. In the neighbouring district, a Tiaochishan Series, largely composed of volcanic material, unconformably overlies a granite, which in the Chufengshan is intruded into the andesite lava, showing the phenomenon of "stoping." The granite is therefore either of Upper Jurassic or of Cretaceous age. Consequently the Tiaochishan Series is believed to be a Cretaceous formation. More recent investigation shows that the Tiaochishan Series forms a continuous sequence with the Chiulungshan Series, if indeed the two are not wholly identical. This raises the whole question as to the age of the Kalgan Series and of some of the tuffaceous formations in the Great Khingan.

The second large basin lies on the western side of the Luliang Range and the northern side of the western Tsinling. It covers north-western Shansi, northern Shensi and a part of Kansu. The deepest part of this Shensi Basin is in northern Shensi where the Paoan Formation, essentially consisting of red sandstones, sometimes false-bedded and sometimes regularly bedded, is estimated by Pan at 2,000 m. in thickness. This estimate essentially agrees with that given by Fuller and Clapp of their Loho, Hwachi and Tanpali sandstones. According to Fuller and Clapp, this red series, which undoubtedly belongs to the Cretaceous, is overlain by the Kingyang and Hwanhsien Series, with alternating beds of green and red sandstones and shales below and greenish shales and sandstones above, having a total thickness of 800 to 1,000 m. The greenish series is overlain by gypsiferous beds. Some notable change of sedimentation apparently took place at the Tanpali Stage. The greenish and the gypsiferous beds may belong to the Upper Cretaceous or early Tertiary. The former correlation is, however, considered to be more probable.

Traced westward, the Cretaceous continues to spread out over an area which is nearly 200 miles wide, extending from the Chienyang district on the south and the Haiyuan district on the north. The deposit still consists of yellow, red and green sandstones, dark shales and a bluish-grey, laminated limestone. In the argillaceous and calcareous beds specimens of *Lycoptera* were found, specifically distinct from the well-known *Lycoptera sinensis* of Shantung. They were described by Grabau under the names *L. kansuensis* and *L. woodwardi*. The latter species, according to the same author, also occurs in the Lower Cretaceous of Shensi.

Estheria and plant remains have been found in these Cretaceous rocks. The southern part of the young mountain, Liupanshan, is almost entirely composed of these strata. Further to the west and the north these beds disappear. On the northern border of the basin they rest at once on Permian, Ordovician and Sinian formations.

The third large basin in which Cretaceous continental deposits were accumulated is the Red Basin of Szechuan. Here the whole series of Cretaceous beds consists of purple-red clays with intercalated yellow-grey sandstones and a bed of grey limestone containing fresh-water shells in the lower part. Black shale and thin layers of coal occasionally occur above the limestone bed. The total thickness of this Tzuliuching Series, as it is called, is estimated at about 900 m., a thickness not incomparable with that of the lower series of the Cretaceous formation in the Shensi Basin. The Tzuliuching Series rests upon the Hsiangchi coal-bearing series of Jurassic age with apparent conformity. It is overlain by purple clay and sandstone of the Kiating and Chungking Series, about 3,000 m. in thickness. These are considered by Heim, Tan and Lee also as Cretaceous.

Both the Shensi and Szechuan Basins are noted for their potential reserve of petroleum. Seepages of oil are actually noted in these areas. Some prospecting borings were made in the Shensi Basin, and have yielded a certain amount of crude oil; but the quantity was found to be insufficient to justify large mining plant and modern methods of transport. The investigation is, however, still being carried on. In the case of the Red Basin of Szechuan the occurrence of oil and natural gas has been known from time immemorial. The oil is reported to occur in six different horizons: one in the Chialing Dolomite of Triassic age, three in the Hsiangchi coal-bearing series, and two in the lower part of the Tzuliuching Formation. Because of free migration of the fluid, it is difficult to ascertain the horizon in which the oil was originally formed. Nor is it definitely known that the oil has been preserved in large quantity, because of the presence of numerous eroded anticlines in which the basal rock of the basin, the Chialing Dolomite, is frequently exposed in the core. Nevertheless there still exist certain anticlinal hills in which the supra-oil-bearing formation has not yet been eroded to the base.

Outside of these large areas isolated patches of Cretaceous deposits also occur. A notable example of these is the Kuichou Series, which is well developed in the Kuichou Basin, a lesser basin formed in pre-Cretaceous time on the eastern side of the Red Basin of Szechuan, but separated from it by mountains composed of Palæozoic strata. The upper part of the Kuichou Series consists of alternating beds of green sandstone and purple shale, some 2,000 m. thick, followed downward by regularly alternating beds of the same green sandstone and purple shale in which *Cyrena, Unio* and *Mycetopus* occur in abundance at intervals. These fresh-water shells especially abound in the lower part of these fossiliferous beds, which aggregate to a thickness of 1,500 m. On account of these fossils the Kuichou Series is referred to the Wealden. The unfossiliferous sandstones and shales overlying these Wealden beds are considered to be Upper Cretaceous. On the eastern border of the Kuichou Basin the Kuichou Series with a basal conglomerate completely overlaps the Patung (Trias) and the Hsiangchi (Jurassic) Series, and comes into direct contact with the Upper Wushan Limestone of Upper Permian age, corroborating the extensive nature of the Ningchinian movement that took place before the Kuichou Series was laid down.

Lower down the Yangtze Valley the green sandstone with intercalated shales is again developed in south-eastern Hupeh, where the questionable Cretaceous beds overlie a coal-bearing series comparable with the Hsiangchi in age. It will be recalled that the Cretaceous Formation in the Shensi Basin terminates at a gypsiferous series. In northern Hupeh and central Hunan, too, beds of gypsum are mined. They occur in the purple-red sandstone and shale. The question is, however, still open whether they belong to the Upper Cretaceous or early Tertiary.

In all these inland areas we find that the Cretaceous is represented by a type of deposit that gradually accumulated in fresh-water basins which may have been undergoing continual subsidence, but have not experienced much disturbance of violent type. Along the coastal provinces and in the mountainous regions in eastern China the conditions are quite different. In connection with the discussion of the post-Jurassic movement reference was made to the occurrence of a tuff-conglomerate and lava flow unconformably overlying the Jurassic in the northern foot of the eastern Tsinling. It was also mentioned that the tuffaceous deposits, such as the Tiaochishan and Chiulungshan Series, overlie the Jurassic in the Western Hills of Peking which form the north-eastern continuation of the Luliang Range. No positive data are yet available to correlate these series beyond the probability that they either belong to the Upper Jurassic or Lower Cretaceous.

More definite stratigraphical data are fortunately available in Shantung, where the Cretaceous strata sometimes directly rest on ancient schists and gneisses, but more often on eroded Palæozoic and Mesozoic formations. From a detailed survey in the Laiyang and Kiaohsien districts it has been established that the Cretaceous Formation in those districts consists of three series. The highest, the Wangshih Red clay, is essentially a red clay with conglomerates and sands containing reptilian remains. The thickness is estimated at 2,000 m. The middle, or the Tuff-conglomerate, 1,200 m. thick, consists of a series of brown tuffaceous conglomerates alternating with beds of red and green clays in the higher and middle horizons and porphyritic lava in the basal part. Some shale and sandstone occur at the very base. Fresh-water shells, plant remains and reptilian bones are now and then preserved in the clays and shales. The lowest, or the Laiyang Formation, consists largely of sandstones with intercalations of greenish or greyish, and rarely red, shales. In the papery shale well-preserved fish, plants and crustacea are found. The genus *Lycoptera* has been long made famous by Sauvage and Smith Woodward. *Brachyphyllum, Sphenolepsis, Pagiophyllum, Palæocyparis, Auracarites, Baiera, Zamites* and *Thinnfeldia* are among the conifers determined by Chow. *Estheria* is fairly abundant. The whole of this lower series is estimated at no less than 700 m. in thickness.

In the Mengyin district, western Shantung, the Lower Cretaceous rests with a break upon a series of red sandstones questionably referred to the Trias, and is overlain by Eocene deposits. Here, the Mengyin Series, as the Lower Cretaceous is named in this basin, consists of greenish sandstones and shales intercalated in its upper part with tuff-conglomerate. Its thickness varies from 380 to 1,240 m. *Unio, Mycetopus, Bithynia* and *Valvata* are among the molluscs that have been described. Some of those forms are specifically identical with those found in the Kuichou Series of the south. Besides these, plants and reptilian remains also occur in the formation.

A detailed investigation has been recently made by C. Y. Hsieh into the Cretaceous deposits in the Western Hills of Peking. According to Hsieh, the Tiaochishan agglomerate with andesitic lavas attains a thickness of about 500 m. to the south-west of Peking. This is overlain by shales, sandstones and conglomerates, some 350 m. thick, which yield *Estheria* in a black shale occurring in the lower part. This, together with the underlying Tiaochishan Formation, is considered to be Lower Cretaceous. Unconformably overlying the Lower Cretaceous are more conglomerates, purple shales and sandstones, some 950 m. thick, with fresh-water limestones and marls intercalated in the upper part. On the occurrence of certain bivalves and plant remains Hsieh assigns this formation to the Upper Cretaceous. This Upper Cretaceous formation is unconformably overlain by the Changsintien Gravel of Eocene age.

In the coastal belt of south-eastern China Cretaceous lava flows are frequent. They are associated with tuffs, conglomerates, sandstones and shales. In the Nanking Hills, the Cretaceous tuff-sandstone rests unconformably upon folded and overthrust Jurassic and older strata, and is itself often highly inclined. Further south-east towards the coast, in Chekiang, for instance, the Kienteh Formation with the usual *Estheria* and fish remains (here they do not belong to *Lycoptera* but to *Mesoclupea* according to Ping) is likewise characterized by rhyolite flows intercalated in a series of tuff, tuffaceous sandstones, agglomerate, black shale and occasional coal seams. This series rests unconformably upon folded Palæozoic strata, and is overlain by massive, bedded rhyolite, which is again succeeded by pyroclastics and conglomerates of the Kiangkow Series.

A similar tuffaceous series capped by bedded rhyolite is extensively developed in Fukien and southern Kuangtung. In northern Fukien it forms the famous Wuyishan. Hence, it is sometimes named the Wuyi Series. But in the Shaowu district in the same province the Cretaceous is mainly composed of a red sandstone with interbedded conglomerate and shales resting upon Jurassic continental beds. This Nancheng Series, as it has been called, may be older than the Wuyi Series. If that is the case, the succession of the

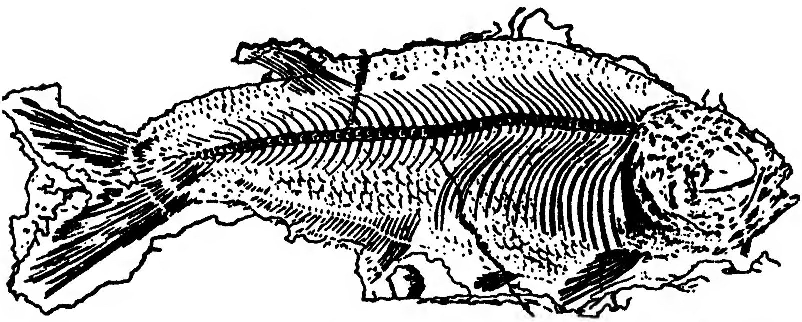

FIG. 54. *Mesoclupea showchanensis* PING and YEN. Lateral view. Cretaceous, Chekiang. (After PING and YEN.)

Cretaceous formations in northern Fukien essentially agrees with that in Chekiang and also with the development in southern Fukien. In the Lungyen and Changping districts the lower part of the Cretaceous consists mainly of a red sandstone with intercalated conglomerates and shales having a thickness of about 300 m.; whereas the upper part is largely composed of rhyolite, andesite, tuff, and quartz porphyry with interbedded red sandstone, and is distinctly unconformable with all the formations that it overlies.

Volcanic ash and breccia of the Repulse Bay Formation unconformably overlie the Tolo Channel Formation of Liassic age in the Isle of Hong Kong. Further inland, the continental facies of the Lower Jurassic is again unconformably overlain by acid and basic lavas of considerable thickness. The question is, however, still open whether these volcanics belong to the Jurassic or Cretaceous. The latter age is generally assumed.

Later Phases of the Yenshan Movements

From the Cretaceous development described above it appears fairly evident that after the Ningchinian Movement a period of quiet sedimentation went on almost all over China covering the Wealden Stage. At the close of that stage volcanic activity broke out in numerous regions with explosive violence. An immense amount of rhyolitic, dacitoid and andesitic lava was poured out along the Great Khingan and in the South-Eastern Uplands extending to the coastal belt of Kuangtung. This period of volcanic outburst was followed by numerous large and small intrusions of granite, granite porphyry and granodiorite. Nearly every region outside of the large Cretaceous basins extending from Central Asia to the south-eastern coast of China was more or less affected by this injection of acid magma. In most cases this phase of igneous activity appears to have been accompanied by a powerful movement. But in the Nanking Hills L. F. Yih seems to be inclined to believe that the granodioritic intrusion preceded overthrusting and folding. Such an interpretation may, however, only indicate the sequence of the connected processes rather than any interval of time that might have elapsed between the arrival of the magma and the tectonic movement.

This main phase of igneous activity and tectonic movement was followed by many minor intrusions of basic nature. Diorite bodies are observed along the Great Khingan and Taihang Ranges, gabbro in the Tsinan district, western Shantung, lamprophyre dykes near Tsingtao, eastern Shantung, gabbro-diorite and lamprophyres in the Nanking Hills, and lamprophyres along the coast of Chekiang, Fukien and Kuangtung. In the Nanking Hills, where Yih and Yu have worked out the sequence of igneous rocks in great detail, it has been established that this phase of minor basic intrusions was followed by minor intrusions of aplite. This final acid phase completed the igneous cycle. Whether a similar sequence of igneous activity is followed in other parts of China is a question which remains to be solved.

These igneous bodies have given rise to many deposits of economic value. In the Sikang region the auriferous quartz veins are probably largely, if not entirely, associated with the granite bodies which arrived in Cretaceous time. Along the Nanling Range and in Hunan, tin, copper, zinc, antimony, wolfram and other ore bodies are as a rule associated with the granite. Metasomatic iron deposits in the Yangtze Valley are often found in the contact zone between granodiorite and limestones. In Chekiang the rhyolite and tuff are often altered to alunite and pyrophyllite through the circulation of sulphuretted hydrogen. These minerals prove to be a useful source-material for alum. Certain varieties of them, together with the agalmatolite associated with porphyry intrusions, are known as soap-stone, and are extensively used for making ornamental objects. Pure nephrite and certain aggregates of amphibole and pyroxene occurring in the Karakash Valley and in other parts of Sinkiang, popularly known as jade, probably also partly arrived during this period of igneous activity. This material was brought to the interior of China throughout historical times in great quantities.

The whole of the Middle and Upper Cretaceous period was practically an epoch of igneous activity and tectonic movements. It may also be rightly called a metallogenic epoch. From the available data we can at least recognize two important phases of tectonic movement. The earlier phase immediately preceded or accompanied the volcanic outburst probably at the end of Wealden times, and is tentatively named the Khinganian movement, corresponding to the Austrian movement of Stille. The later phase occurred towards the end of the Cretaceous, being accompanied or immediately preceded by enormous masses of granite intrusion all along the south-eastern and southern coast, and followed by minor intrusions of basic nature. This phase of tectonic movement is named the Mincheian, corresponding to the main phase of the Laramide movement in North America.

Early Tertiary Formations

Eocene formations are still little known in China. But this does not imply that they are scarcely developed. G. J. Andersson first found in the Yuanchu Basin, southern Shansi, a coarse conglomerate becoming finer towards the upper part. In this deposit Eocene rodents and shells of *Planorbis* and *Physa* occur. About 100 km. west-south-west of the Yuanchu Basin Tsao found a series of red-brown conglomerates, sandstones and marls which contain lenticular beds of gypsum. The whole series amounts to about 600 m., and is unconformably underlain by Palæozoic strata and unconformably overlain by gravels and a red loam. The fresh-water shells from this deposit are tentatively referred to the Eocene. Similar deposits, occasionally with gypsum and fresh-water limestones, are distributed in the Pinglu, Mienchih, Hsinan, Hantan and Changteh districts in northern Honan. In the Mengyin and Laiyang Basins, Shantung, the Kuanchuang Series consisting of red sands, clays and conglomerates with intercalated dark sandstones, shale, marls and a fresh-water limestone, reaches a total thickness of 600 to 1,670 m. It has yielded Eocene gastropods and mammalian remains. This series is concordantly underlain by the Cretaceous formation. In the neighbourhood of Peking the Changsintien Gravel, with rodents and Amblypods either of Upper Eocene or Oligocene age, rests, however, with a distinct unconformity, upon the older beds. Eocene conglomerates, sandstones and clays, several hundreds of metres thick, are reported to occur in southern Honan, on the northern side of the Tsinling Range. No stratigraphical detail is, however, yet available.

More extensive is the questionable Eocene development in the Weiho Valley, southern Shensi, and in a number of basins in eastern Kansu. The beds are generally composed of conglomerates, red sandstones and red clays. In central Shensi these beds are associated with lacustrine deposits. In the Kuyuan district, Kansu, the Eocene formation consists of a series of moderately folded sandstones and conglomerates with a fossiliferous fresh-water limestone and thin beds of gypsum. This formation appears to extend over a wide area in Kansu and Ninghsia, and is well exposed along the upper Huangho Valley. South of Kuyuan, similar conglomerates are developed in the Tienshui, Lungsi and Minhsien districts. These are practically all that we know of the Eocene of northern China.

An important section of early Tertiary formations is recorded by C. Li and S. Chu in the eastern Tsinling on the border between Hupeh and Honan. There, the Eocene series overlies the Sinian limestone, and begins with a basal conglomerate, which is succeeded by red sandstones with sandy shales gradually merging upward into a thick sequence of marls and sandy shales. From the marls in the upper part of the sequence *Lophioletes* or *Cænolophus, Sinohadrianus* (turtle) and other animal remains were procured. The fauna indicates a close relation to that of the Irdin-Manha Formation of Upper Eocene age developed in Mongolia. This Fanchuang Series, as it is called, is overlain by the Wushaoling Marl, believed to be of Oligocene age.

South of the Tsinling Range, a darkish red sandstone with occasional beds of conglomerate and sandy clay is extensively distributed all along the Yangtze Valley. This formation is equally well developed in the Nanling Range, Kuangtung, Kuangsi and the South-Eastern Uplands. It generally unconformably overlies the older formations, though the unconformable contact is not always observed. Various local names have been given to this red formation. But the lithological character is always essentially the same —a well-bedded, soft sandstone, brownish to dark red in colour, and rather porous in texture, not infrequently intercalated with clays and conglomerates, the latter especially abounding towards the base.

In the Ichang district, western Hupeh, the red formation is locally known as the Tunghu Sandstone. Here, it contains a fresh-water limestone, some 30 m. thick, yielding small gastropods probably belonging to *Bithynia*. In central Hunan and northern Hupeh beds of gypsum are intercalated in the red formation. In the lower Yangtze Valley it is named the Pukow Series. Undoubtedly some of these local formations belong to the Eocene. The possibility is, however, not excluded that others may belong to the Upper Cretaceous or even Oligocene. Oligocene deposits are so far little known in China. The most important formation belonging to this period is the plateau basalt of Mongolia extensively distributed to the north of Kalgan. The lava sheets are occasionally intercalated with lignite-bearing clays and sands, in which occur *Pinus, Comptonia, Carpinus* and *Phyllites*. The same formation extends to the Fanchihsien district, northern Shansi. A similar lignite-bearing formation is developed in the Wuchuan district along the Inshan Range. There, again, contemporaneous lava flows are found in the coal-bearing beds. In most of these districts the Oligocene coal is of no economic value. In Manchuria the case is, however, different. The Chalainor coalfield, near Manchuli, and the Fushun coalfield in South Manchuria yield Oligocene coal of great economic importance. In the Fushun district the coal proves to be a bituminous variety, and is being worked on a large scale.

Basaltic flows have been observed in the Taian, Ssushui and Feihsien districts in western Shantung, where the eruptions took place, according to C. Li, after the disturbance which affected the early Tertiary formation. Young basalts are found here and there all along the south-eastern coast down to the Isle of Hainan. In southern Hunan a basaltic body, apparently in the form of a neck, penetrates the young red sandstone. No lava flows are, however, observed in the neighbourhood. These occurrences are at least partly comparable in age with the basaltic flows of southern Mongolia.

A remarkable series of alkaline intrusions has been described by E. T. Nyström and S. L. Tsao. They occur in the middle part of the Luliang Range and in the southern part of the Hoshan Range, central Shansi. The igneous series comprises, according to Nyström, three stocks, all differentiated from a parental akerite magma. In the

Chaocheng district a granitic and syenitic "evolution" results ultimately in nordmarkite and ægirine-augite-syenite with nosean. In the Linfen district a granitic, syenitic and dioritic stem leads up to quartz-porphyry, ægirine-augite-syenite and banatite respectively. Only in the Tzechingshan area does a syenite stock differentiate to nepheline-syenite, tinguaite, and leucite-tinguaite. Other localities where alkaline rocks are known to occur are in eastern Yunnan and Sinkiang. The age of these occurrences is not known with certainty. Nyström and Tsao are, however, inclined to assign a mid-Tertiary age to the Shansi alkaline series.

In Mongolia and the Ordos region, the Oligocene deposits yield remains of the monstrous *Baluchitherium*. This rhinoceros-like creature had a robust body, long neck, a long and narrow head, was about 13 feet high to the shoulder, and could easily raise its head to a height of 16 feet. Unlike rhinoceros, it had no horn. This mighty beast must have roamed in Central Asia, for its scattered remains have been found from Bugti to Mongolia.

Maoshan Movement

The young red formation mentioned above is usually folded and faulted, with a dip varying, as a rule, from 20° to 35°. But in places folding may be so intense that the red beds dip at more than 60°, and, rarely, they are flung on end. It is thus clear that considerable movements have taken place since the deposition of the red beds. In association with the Pukow Formation sometimes occurs a brilliantly red sandstone named the Chihshan Sandstone. The two have never been observed in superposition. Y. Y. Lee, however, recently reports from southern Anhui that there the Chihshan Formation, which is equivalent to the Tatung Conglomerate of Richthofen, actually rests, with unconformity, upon the Pukow beds. At all events, the fact that the Chihshan Sandstone is always only gently inclined in contradistinction to the moderate or high dip of the Pukow beds occurring near by, leads us to believe that the Chihshan is younger than, and unconformable with, the Pukow. The exact age of the former is, however, still unknown. These circumstances would seem to suggest that folding and sometimes overthrusting, which involve the Pukow Formation, namely the Maoshan movement, occurred before the Chihshan Stage.

This movement obviously varied in intensity from place to place. In old-established tectonic zones the disturbance is usually more manifest. A striking example of this movement is found in the Maoshan Hills, near Nanking. There, the Pukow Formation is overthrust towards the west on the eastern side of the hill-range, and towards the east on the western side of it. The Pukow beds, when not overthrust, often stand on end or even reversed at the flank of the hill-range. Near the village of Puchin, north of Nanking, the Pukow Formation is thrust upon the Triassic limestone. Similar examples may be cited from the Chinyang district, southern Anhui.

In the eastern part of the Nanling Range, the red beds are clearly unconformable with the formations that they overlie. Such sharp folding and overthrusting as are developed in the Lower Yangtze Valley, however, have never been observed. In the Sikang area, and perhaps in the Nanshan Ranges, this mid-Tertiary movement has almost certainly played an important part, giving rise to the present high relief. But how far it has accentuated the late Mesozoic folds is a question that remains to be answered. In northern China numerous normal faults with large throws are attributed to this epoch of tectonic movement.

Late Tertiary and Early Quaternary Deposits and Disturbances

In connection with the hunting of early man, the staff of the Cenozoic Laboratory of the Geological Survey of China has contributed much in elucidating the geological changes that have taken place in northern China since early Pliocene time. Some five cycles of erosion and deposition have been recognized within this last period of geological history. We have already seen that the Eocene deposits on the border of the Shansi Plateau are often tilted to a moderate extent. They, together with the underlying

Mesozoic and Palæozoic formations, were reduced to an extensive peneplain corresponding to the Tanghsien Stage of Bailey Willis. On the warped surface of this peneplain are deposited certain gravels which still evade exact dating. Then the Paotuh Stage of sedimentation followed. This stage of deposition began with red clays containing *Prosiphneus* and *Hipparion richthofeni* as the leading fossils. Later on, gravels were formed in local basins. With these fluvio-lacustrine formations the First Cycle closed. These deposits belong to the Lower Pliocene or the Pontian Stage.

The Hipparion Clay is probably widely developed in the southern part of the Mongolian Steppe, to the north of the Inshan Range, and in Jehol. It is definitely known to

FIG. 55. Left upper cheek-teeth of *Hipparion richthofeni* KOKEN. × ¾.

occur along the Sangkanho Basin, south-west of Kalgan. Further south, the fossiliferous clay forms a broad belt running across Kansu, Shensi and Shansi from the west to the east. The same clay is again exposed on the southern side of the Weiho Valley and in the northern part of Honan, following the northern foot of the Tsinling. The gravels and sandy deposits are scattered and more irregularly distributed. A fairly extensive basin of these lacustrine deposits occurs, however, in central Shansi on the south-eastern side of the Fenho. Another basin of similar nature is developed in the Dalainor region in Mongolia. A third is known in the Mongolian Altai.

The Second Cycle began with a period of erosion which was succeeded by the formation of terrace gravels along the Huangho, and of a red loam with *Prosiphneus intermedius*. This stage of deposition is known as the Ertemte Stage.

The Third Cycle commenced with the Fenho Stage of gorge cutting and an extensive and uniform erosion in the Gobi region, the result being the production of the Gobi peneplain. This period of erosion was succeeded by first the formation of gravels in Ordos and Mongolia, then the red and reddish loams with numerous calcareous concretions and with the characteristic fossil, *Siphneus tingi,* and, finally, the Nihowan Beds of fluvio-lacustrine origin usually richly fossiliferous. These fresh-water and land deposits are generally termed the Sanmen Series. They contain *Melania,*

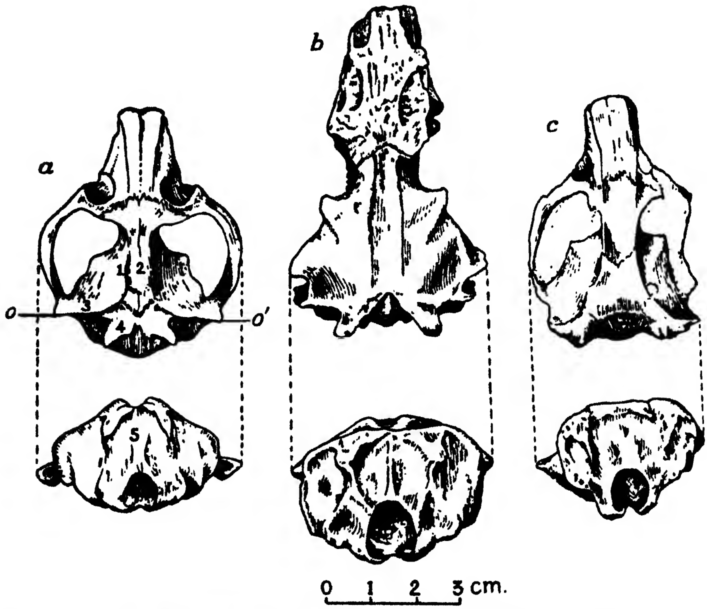

FIG. 56. Top and occipital views of three *Siphneus* skulls; a, *S. fontanieri* M. EDW.; b, *S. arvicolinus* NEHR.; and c, *S. tingi* YOUNG. Abbreviations: o-o', occipital plane.

Lamprotula, fishes, plant remains such as *Amelanchier, Ulmus, Leguminosites* and *Acer,* land snails, and a large assemblage of vertebrates, of which *Equus, Hipparion* and *Eucladoceras* are among the common types. *Rhinoceros* is also fairly common.

Of all the Pliocene formations in northern China, the Sanmen is probably the most extensive and is certainly the best known. The red and reddish loams approximately follow the sites of deposition of the Hipparion Clay. But, in addition, they have been found in North Manchuria and Shan-

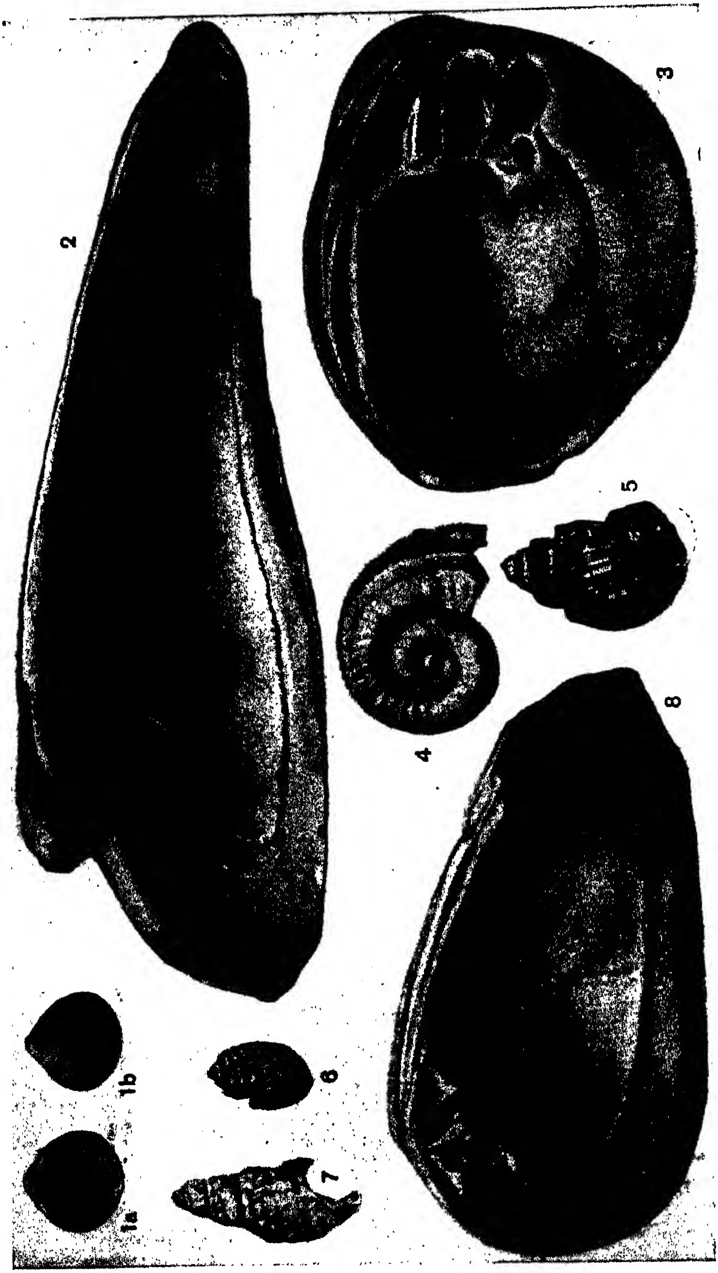

FIG. 57. PLIOCENE MOLLUSCS.

tung along the Kiaotsi Railway. The lacustrine facies is also rather extensively developed. Classical sections of these deposits have been worked out at Nihowan along the Sangkanho Valley, in the Taiku and Yunchuchen Basins in central Shansi, and along the course of the Huangho, east of Tungkwan, including the type locality, Sanmen. In the Sangkanho district lava flows are actually found in the Sanmen beds, though elsewhere in northern China similar occurrences have not been recorded.

In southern China Pliocene deposits are not so well known as in the north. Some argillaceous limestones, sandy beds, marls and laminated clays have been found above the Chihshan Sandstone and below the Yuhuatai Gravel near Nanking. The thin-bedded, sandy limestone is, in places, crowded with fish-scales, and contains shells of *Bithynia*. The white marl is sometimes intercalated with beds of basalt, and sometimes mixed with pillows and balls of lava. In all probability this series of lacustrine deposits represents the Upper Pliocene, though an older age would seem to be demanded by physiographic arguments.

Lacustrine deposits with viviparid shells are known in eastern Yunnan. A similar formation is developed in the upper Sikiang Valley, notably in the Napo and Nanning Basins. In these basins the clayey and sandy deposits bear thin seams of lignite and shells of unionids and numerous viviparids, including the genera *Melania* and *Tulotoma*. It will be remembered that *Melania* often occurs in the lower part of the Sanmen Series of northern China. Odhner and Hsu, who have independently worked out these faunas, would both consider them as Pliocene, and Odhner com-

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EXPLANATION OF FIG. 57.

1 a, b. *Corbicula fluminea* MÜLLER. Sanmen Series. × $\frac{4}{5}$.
2. *Solenaia carinata* HEUDE. Sanmen Series. × $\frac{1}{2}$.
3. *Lamprotula antiqua* ODHNER. Sanmen Series. × $\frac{2}{3}$.
4. *Valvata* sp. Pliocene Shale, near Nanning, Kuangsi. × 10.
5. *Tulotoma kwangsiensis* HSÜ. Napo, western Kuangsi. × $\frac{4}{5}$
6. *Paracampeloma ovata* HSÜ. Napo, Kuangsi. × $\frac{4}{5}$.
7. *Melania aubriyana* HEUDE var. *napoensis* HSÜ. Napo, Kuangsi. × $\frac{4}{5}$.
8. *Cuneopsis maximus* ODHNER. Sanmen Series. × $\frac{3}{4}$.

pares the fauna of Nanning with that of the Levantine Stage of Rumania.

For lack of palæontological evidence, and on account of more varied tectonic and physiographic conditions, the physiographic stages in southern China are less clear and less satisfactorily interpreted as far as the older stages are concerned. C. Y. Hsieh, C. C. Liu and L. F. Yih recognized, however, an extensive but raised peneplain in western Hupeh varying in altitude from 1,700 to 2,000 m. They name this oldest recognizable peneplain the Ohsi Stage of erosion. C. Li and S. Chu observed the same peneplain in southwestern Hunan and in the Nanling Range between Hunan and Kuangsi. Yih and Hsieh assign this peneplain to the late Oligocene or early Miocene. Barbour, however, would place this stage in the Eocene, and compares it with the Peitai Stage of northern China. The last-named author further distinguishes a Tsinling Stage (Willis) in the Middle Yangtze and a Tsientang Stage in the Lower Yangtze Valley, and Kuanho and Loho Stages in the central and eastern Tsinling, and compares these erosional surfaces with the Tanghsien Stage in the north. According to Barbour, all these surfaces were produced in Miocene times or slightly earlier. The same observer adds that certain intermontane deposits in the Upper Yangtze, the red loams and mottled clays in the Middle Yangtze, the Yuhuatai gravels and loams in the Lower Yangtze (Yuhuatai Stage), the intermontane gravels and red clays in western Hupeh (Shangyuan Stage), red loams in the Hanchung Basin (Tanchiang Stage), and reddish loams in the Loho Basin (Chiaho Stage), eastern Tsinling, are to be correlated with the Paotuh Stage of the north, and places them in the late Miocene or early Pliocene. This stage of physiographical development is supposed to have ended with a prolonged deposition of soil and loam under lateritic conditions during late Pliocene times. A note of warning must, however, be added to this useful generalization against complications arising from the correlation of the unfossiliferous deposits. The name Nanling Stage is also introduced to denote a stage of erosion next to the Ohsi. But in view of the fact that the physiographical history of the Nanling Ranges themselves is yet hardly touched upon, the application of this term might, for the sake of safety, be suspended, at all events for the time being.

Post-Pliocene Disturbance

In and around the Plateau region of northern China the sediments belonging to the Pliocene Period generally lie

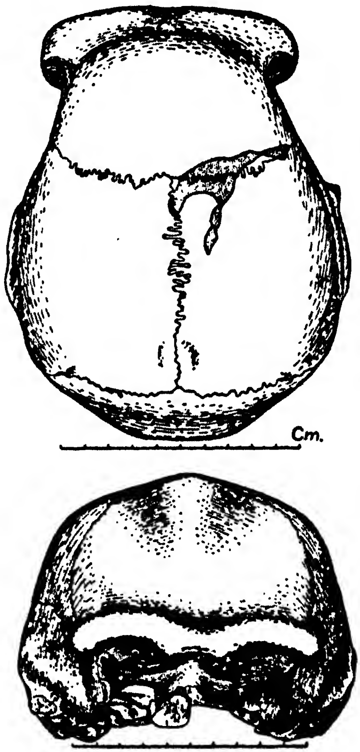

Fig. 58. Skull of *Sinanthropus* found by W. C. Pei in Choukoutien, near Peking, 1929. (After Black.)

in a horizontal or almost horizontal position. Only on the borderland of the plateaux do they appear to be sometimes affected by normal faults. But in the mountainous zones, such as the northern foot of the Nanshan Range, Mongolian

Altai, and the western continuation of the Inshan Range, they are often folded in a remarkable way. This movement may have extended to the mountainous zones of northern and southern China; but lack of stratigraphical evidence in certain areas where disturbance appears to have taken place in recent times makes the correlation exceedingly difficult. Occasional lava flows as recorded in the Nihowan and Nanking areas suggest, however, that China proper was not completely at rest towards the end of Pliocene times.

The Choukoutien Deposit

Now we come to the Fourth Cycle as recognized in northern China. This cycle also began with an extensive erosion which was accompanied or followed by deposition in caves or fissures in which the early man, *Sinanthropus pekinensis,* made his home. He had relatively a large cranial capacity, narrower and higher coronal contour than in *Pithecanthropus,* and teeth of "generalized hominid type," according to Davidson Black. As to his relation to the Java man, we know very little but that it is rather remote. He evidently knew fire and made crude stone and bone implements. In the same cave in which *Sinanthropus* occurs many tons of animal bones have been excavated. Among them are *Elephas, Rhinoceros tichorhinus,* rodents, pigs, deer, antelopes, tigers, buffaloes, etc. Seeds of *Celtis* are believed to have been used by the Peking man as food.

It is generally held that the Red and Reddish Loams, which occur so extensively in northern China with *Siphneus fontanieri* as the characteristic fossil, also belong to the Choukoutien Stage. At the same time it should be borne in mind that the Choukoutien deposit is entrenched in isolated caves. Its correlation with other formations can only be deduced by palæontological and physiographical arguments. That these loams and the Choukoutien deposit itself belong to the early Pleistocene seems, however, unquestionable.

The Fifth Cycle recognized in northern China began with the Chingshui Stage of erosion, which was followed by the deposition of the Malan Loess, a true æolian product of yellowish grey colour, covering vast areas of northern China. In this wind-blown material often occur ginger-shaped bodies of limy concretion, known as "loess kinder," and beds of gravel indicating pluvial times during this final stage of desiccation. The fine dust was evidently brought

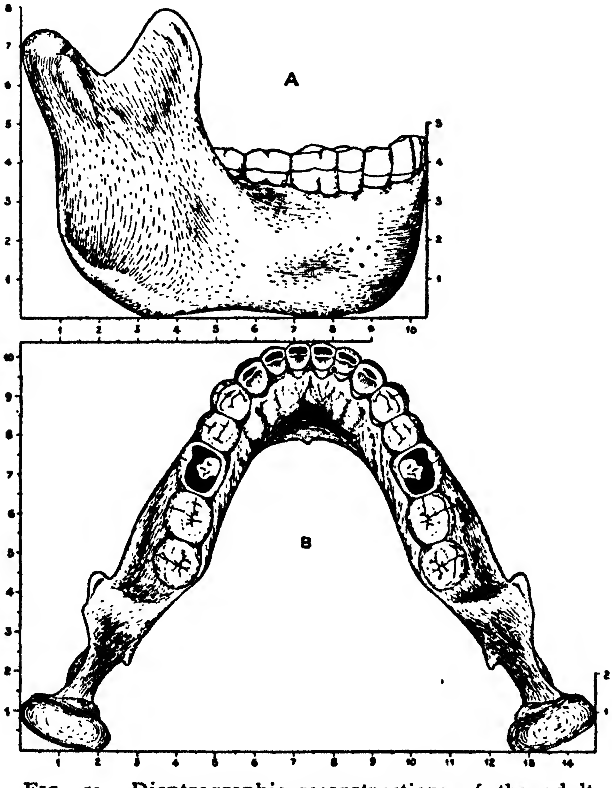

FIG. 59. Dioptrographic reconstructions of the adult *Sinanthropus* jaw; A, labial; B, occlusal view. That part of the symphysis region which is conjectural (as not actually represented on any of the original specimens) has been indicated by interrupted lines in each of these reconstructions. Scale in centimetres. (After DAVIDSON BLACK.)

from Mongolia and central Asia by a prevailing north-west wind. Land shells, such as *Helix*, and ostrich eggs are the organic remains usually found in the Malan Loess. The famous *Mastodon* fauna apparently associated with scattered representatives of mammoth probably flourished either immediately before or during the Loess-forming period. *Rhinoceros tichorhinus, Bos, Elephas* and mammoth are also found in the Sjara-osso-gol and Sungari formations of Mongolia and Manchuria respectively, which are equivalent to this stage. Remains of mammoth have been found farther south, *e.g.*, northern Honan. The vertebrate fauna of northern China is, as a whole, characterized by the presence of numerous *Mastodon,* whereas in the south, *Stegodon* predominates. Although the processes of transportation and re-deposition of Loess are still going on at present in the north-western part of the country, yet the principal Loess-forming period belongs to the past. In numerous places the Loess plain is rather deeply trenched. To this recent stage of erosion the term Panchiao Stage has been applied. In the middle course of the Huangho, Hsieh, however, prefers the name Huangho Stage to Panchiao.

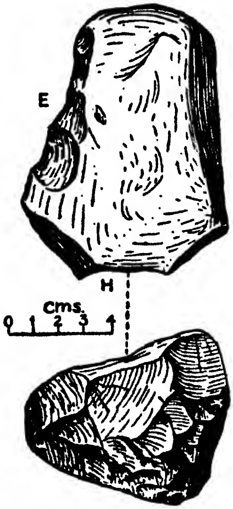

FIG. 60. Small chopper in greenstone with a prepared heel H, and the edge E chipped by use. This advanced form of stone-implement is associated with many rather crude types among the *Sinanthropus* remains.

In the Yangtze Valley our knowledge regarding the recent geological and physiographical history is still largely in a state of confusion. What we know with certainty is a river terrace, about 20 m. high on the average, especially well developed all along the lower Yangtze Valley. This terrace appears to have originated from the last stage of river erosion, and would therefore probably represent the Pukiang Stage of Barbour. Whether it has any connection with the alleged recent universal lowering of sea level, as has been emphasized by R. A. Daly, is still problematic.

This terrace is sometimes formed by bevelled red sandstone alone or by gravels and loams resting upon the eroded red beds. The upper loam is usually a reddish yellow sandy clay, named the Siashu Loam, and contains numerous land and fresh-water shells in places. At Lungtan, near Nanking, the fauna collected and studied by Hsu consists of *Traumatophora, Ganesella, Eulota, Clausilia, Buliminus, Opeas, Bithynia, Fossarulus, Diplommatina* and *Cyclophorus*. Seventy-six per cent. of the number of species determined are still living. This percentage will probably increase as our knowledge of the living species widens. The gastropods of the Sanmen and Choukoutien Stages embody only 22 to 30 per cent. of the living forms, so far as is known. Hsu is therefore led to conclude that the Siashu Loam is much younger than the loam of the Choukoutien Stage, and that it is probably comparable with the Malan Loess of the north.

Immediately below the Siashu Loam, which sometimes contains basal gravel, appears a series of reddish and red clays. The latter are often mottled with numerous blotches and streaks of white, irregularly arranged. These mottled red clays attain an extensive development all over southern China. They do not necessarily belong to one and the same stage. Underlying the red clays is sometimes another red clay mixed with transported, jagged boulders, and sometimes gravels with all the pebbles well rounded and waterworn. Whether the Yuhuatai Gravel of Nanking belongs to this stage of deposition is yet uncertain. Nor is it definitely established that the Yaun Gravel so extensively developed in western and eastern Szechuan is a contemporaneous formation. A possible implication of this extraordinary clay-and-boulders deposit will be dealt with in Chapter IX. The mesa basalt in the Nanking area was probably poured out immediately after the deposition of the Yuhuatai Gravel; but in places beds of lava appear to be intercalated with the Yuhuatai Series.

Among the most striking changes that have taken place in China during recent geological times is the regional uplifting and subsidence that have been recognized in different areas. The evidence gathered, though it still requires careful co-ordination, is nevertheless conclusive as regards a general movement. At Tientsin, marine sands and clays with *Arca, Cyclina, Siliquaria* and *Mactra* have been found in an artificial exposure at a level of about the Taku Datum. Boreholes made in the same city showed the presence of sands and clays with fresh-water shells down to a depth of more than 507 feet below the marine layer which is exposed on the surface. This is undoubtedly due to recent subsidence. On the other hand, signs of recent elevation are not lacking along the foot of the Western Hills of Peking. The Plain of Peking would thus seem to fall within a sinking land which forms a part of a geosyncline in the making.

In the mountainous region of western China nearly all observers agree that rapid uplifting has been going on. The Kinshakiang, with its north-south tributaries now forming the headwaters of the Yangtze, is believed to have drained its waters to the south through the present watershed in northern Yunnan. The lowest point of this watershed at Tsinpukou, or the wind-gap of Gregory, is about 600 m. high above the present river. Gregory assumed that this was the gap through which the Kinshakiang formerly ran southward to join the present Red River. Lee, however, considers it more probable that the ancient river course followed a series of raised open valleys leading from the north to the south past the Erh-hai, and then entered into the Red River Valley. It is of interest to note that the lakes situated in these elevated north-south valleys are all of a comparable height, about 2,300 m. in altitude. The highest saddle reaches 2,612 m. If the Kinshakiang actually followed this course in early Pleistocene or Plio-Pleistocene time, Deprat's estimation of elevation of 2,000 m. in that area since early Pleistocene time would hardly seem to be an exaggeration. Instead of rising on the part of the high land, Gregory, however, advocated sinking on the part of the low land.

At all events, it can hardly be doubted that the high mountains of western China have undergone a considerable uplifting movement against the neighbouring lowland in recent geological times. Indeed, it is not unlikely that such a relative movement is still going on. A striking case in this connection may be cited. In the neighbourhood of Tatsienlu, and on the eastern side of the Minya Gongkar, Heim has actually observed the fluvio-glacial water cutting its own deposit formed in the glacial age to a depth of about 100 m. There is clear evidence that the glaciers in the high mountains have retreated considerably in recent geological time. The argument that such stream erosion might be due to increased precipitation in post-glacial time can therefore be safely ruled out. Thus we may agree with Heim that the mountain ranges in western China have been elevated since the glacial age. Similar evidence of recent uplifting is available in the Himalaya. It would seem probable that the Tibetan massif, with the lofty height that it has already attained, is still undergoing elevation.

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CHAPTER V

CATHAYSIAN[1] GEOSYNCLINES AND GEANTICLINES

In following up the sedimentary record of China we have seen how the Palæocathaysian geosyncline was transformed into the Mesocathaysian geosyncline, and then into the Neocathaysian geosynclines now still in the active state of growth. We have dealt with these earth-troughs as sites of deposition. We shall now consider them in their tectonic aspect—as gigantic, complex synclines or synclinoria accompanied by anticlinoria.

The Palæocathaysian Geosyncline and Palæocathaysia

Evidence has been adduced to show that the Palæocathaysian geosyncline was practically in continual existence from the Sinian down to the later part of the Ordovician period. The initial development of this trough was marked by the accumulation of clastic sediments which nearly always form the lower part of the Sinian strata. Later in the same period, deposition of massive limestones followed. Subsequent erosion has removed much of these limestones, and, consequently, the full extent and shape of the trough cannot be so clearly recognized as one might desire. Nevertheless, from the scattered remnants of the Sinian limestones extending from South Manchuria to the south-western provinces of China, the broad features of the incipient geosyncline can be deduced without much difficulty.

Two important facts stand out prominently. Firstly, the general trend of the elongated trough, whatever might be its local irregularities, was from the north-east to the south-west. Secondly, the trough embodied several local basins which were more or less separated from one another,

[1]A term originally introduced by A. W. Grabau.

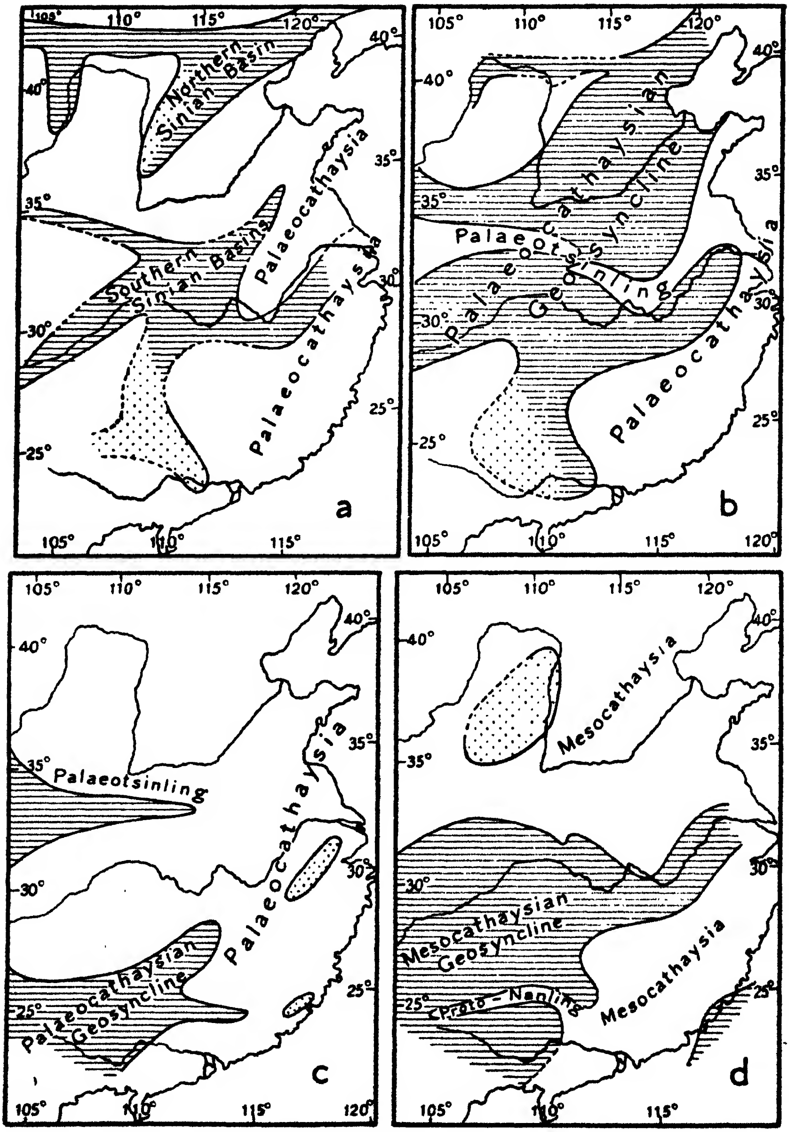

Fig. 61. Hypothetical restoration of the general trend of the Palæo- and Meso- cathaysian Geosynclines and other related features. a, late Sinian; b. Middle Ordovician; c, Devonian; d, Triassic.

at least in their initial stage of development. The largest of these basins covered parts of South Manchuria, southern Jehol, northern and western Hopei, and the greater part of Shansi. This local basin also assumed a north-east trend. Greatest subsidence within this basin occurred in the borderland between Jehol and Hopei Provinces, where the sequence of Sinian strata amounts to no less than 5,370 m. in thickness, of which the upper 3,870 m. is largely composed of limestones. Upward, they pass into the Lower Cambrian without any noticeable break. This extraordinary depression seems to be connected with the development of an east-west zone of subsidence, of which mention will be made when we come to discuss the Inshan zone of orogeny (p. 246). From the region of maximum subsidence, the basin extended towards the Shansi area, becoming ever shallower as it extended further south-west. In southern Shansi and northern Honan the Sinian Limestone is frequently absent. There, an insignificant thickness of detrital sediment, supposed to be of Sinian age, unconformably overlies the old metamorphic series, and directly underlies fossiliferous Cambrian or Ordovician. Even this deposit is not always present.

No Sinian strata occur in the Shantung massif except on its southern border, *e.g.*, in the Yencheng district. From this area the Sinian Limestone, with a thickness of 450 to 500 m., extends towards the south-west, forming a broad belt of exposure between the Lower Palæozoics of the Huaiyin Hills on the west and the old metamorphic rocks on the east. How far this Sinian Limestone extends westward and south-westward below the Palæozoic and recent deposits in the North China Plain is a matter for conjecture. But it is fairly certain that the region to the east of the Sinian terrain lay outside the basin. This tract of old peneplaned land-mass, together with the Shantung Peninsula, represents, in fact, the western border of a geanticline belonging to Palæocathaysia.

The coastal province of south-eastern China is likewise free from Sinian sediment. Silicified Sinian limestone, interbedded with shales, begins to appear in southern

Anhui. The limestone increases in thickness towards the southern flank of the Central Tsinling. In the Ichang Gorge, the easternmost one of the Yangtze Gorges, and in western Hupeh in general the Sinian formation, beginning with sandstones and tillite and ending with a massive limestone, attains a thickness of no less than 800 m., of which more than 500 m. are composed of limestones. These limestones are traced to the south-eastern border of the Red Basin of Szechuan, south of Chungking, and to the neighbourhood of the Omeishan on the south-western border of the same basin. In the last-named locality, the Sinian Limestone reaches a thickness of 800 m. overlying the Omeishan Granite. Clastic rocks supposed to be of Sinian age are reported to occur in the neighbourhood of Kweiyang on the Kweichow Plateau. Further south, detrital sediment assigned to the Sinian appears in the western Nanling Range. Thus it appears fairly clear that the Sinian basin in southern China occupied an area more or less parallel to the Tsinling in its eastern part, but from the Gorge district westward it stretched to the west-south-west. This is apparently the direction of its axis or the zone of maximum subsidence, not incomparable with the northern basin in its general trend.

From early Cambrian to late Ordovician times, the growth of the Palæocathaysian geosyncline as a single trough of vast size is clearly in evidence. The western part of the Liaotung-Shantung massif, and parts of southern Shansi and northern Honan, were submerged, resulting in the formation of marine limestones. The trough expanded at the expense of the old land, and continued to extend, after a partial interruption by land barriers in the eastern Tsinling, to the south-west. In that direction probably lay the axial part of the trough, although the invading marine water was fluctuating. Cambrian and Ordovician strata of marine origin have been observed in western Hupeh, parts of the Kweichow Plateau, and in the south-eastern and south-western border (Omeishan) of the Red Basin of Szechuan. In Yunnan, however, the main site of deposition was in the eastern part of the province during the Cambrian, but it migrated to the western part of that province in Ordovician times.

A deep channel running along the Yangtze Valley in Middle Ordovician times seems to be associated with the land barrier which existed on the site of the present Tsinling Range. From the tectonic point of view, it belongs, therefore, to the east-west zone of disturbance, or the Tsinling geosyncline, rather than to the Palæocathaysian geosyncline, which has a north-east trend.

Shallow-water deposits, such as sandstones, shales and thin beds of impure limestones, form the marginal facies of the sediments in the Palæocathaysian geosyncline. These deposits are widespread in southern Anhui and north-western Chekiang, with sandstones becoming more predominant towards the south-eastern coastal belt. In the south-eastern coastal region itself, *e.g.*, southern Chekiang and Fukien, no sediment of Cambrian and Ordovician age is present. This region represents the southern part of Palæocathaysia, which, together with the Liaotung-Shantung massif, stood throughout the Sinian-Ordovician periods as a persistent land-mass on the eastern side of the Palæocathaysian geosyncline, separating the latter from the Pacific. The oldest known marine sediment in Japan belongs to the Upper Devonian. The Chichibu System of that country possibly includes clastic rocks of Lower Palæozoic age; nothing, however, is known indicating widespread marine conditions throughout pre-Devonian times. Parts or the whole of the Sea of Japan and the Yellow Sea were apparently the site of this old land, Palæocathaysia.

Similarly, no Cambrian deposit occurs in the Ordos region. And there the Ordovician is only represented by graptolite-bearing shales and limestones of no great thickness. Comparing these meagre deposits with the massive Ordovician limestones developed in north-eastern China, there can be no doubt that here we are approaching the north-western margin of the Palæocathaysian geosyncline.

Little is known as regards the relief of Palæocathaysia. The sediments in the geosynclinal area suggest, however, that the trough was not of a symmetrical form, but that its deepest part generally lay much nearer to its western margin than to its eastern. The widespread deposits of shallow-water origin in the Lower Yangtze province seem to indicate the presence of mud deltas, which are not replaced by coarse clastics but by fine sands as they are traced to the shore of the old land to the south-east. Such evidence is obviously against the assumption that Palæocathaysia presented a bold front towards the inland water. On the other hand, a mighty sequence of Sinian and Cambro-Ordovician strata dies out rather rapidly when followed towards the north-west. This asymmetrical form of the geosyncline is more or less repeated by its modern counterparts, the Neocathaysian geosynclines. We shall return to this feature when we come to discuss the origin of these broad tectonic structures.

At the end of Ordovician times the northern part of the Palæocathaysian geosyncline was elevated. What was left of the trough was now restricted to southern China, extending from the Lower Yangtze Valley, past Hunan, Kweichow and Kuangsi, and finally reaching Yunnan. This south-westerly trough was undoubtedly connected with the Tsinling geosyncline, which stretched nearly east-west along the site of the present Tsinling, and deepened towards the west. The absence of Silurian strata in the south-eastern and south-western parts of the Red Basin of Szechuan, and probably on the north-western border of the Kweichow Plateau, marks a land area which separated the western part of the Tsinling geosyncline from the contracted Palæocathaysian geosyncline.

After the Caledonian movement, the Lower Yangtze province stood above water. Elsewhere, the Palæocathaysian geosyncline remained essentially unaltered during Devonian times. Thus we are enabled to see that the remnant of the Palæocathaysian geosyncline in the Silurian-Devonian periods still bore a north-east trend. The Caledonian movement evidently served to deepen and, perhaps, to narrow down the trough, as indicated by the deposition in it of a considerable thickness of limestones in the Devonian period. At the same time the old land on the south-east pushed its western boundary into the inland sea. If the lower part of the Wutung Sandstone in the Lower Yangtze Valley really belongs to the Devonian, the presence of coarse clastics in this formation would mean that the land was in fairly high relief. The entire absence of Siluro-Devonian deposits in Fukien shows that that region stood well away from the inland water.

The Palæocathaysian geosyncline, thus reduced and localized in Siluro-Devonian times, continued to exist in the Lower Carboniferous. During the Tournaisian epoch the contracted trough experienced little change save a limited extension to the north-east. In Viséan times the main trough still remained in the same position, but a branch extended into north-western China probably by way of the western Tsinling.

The great marine flood that came upon China during Middle Carboniferous times renders it rather difficult to locate the position of the Palæocathaysian geosyncline. A further complication arises from the fact that Moscovian limestones play a relatively important part in the stratigraphical development of central Japan. Obviously, then, we can no longer speak of Palæocathaysia as a single and broad geanticline. Spreading of the Tethys at this stage, as conceived by Edward Suess, presupposes a fundamental change in the surface features of the continental masses. Whatever may be the complication brought about in the Eurasian Continent as a whole, we can still recognize the broad features of the Chinese area washed by the vast sheet of epicontinental water.

In northern China the invading sea was uniformly shallow and fluctuating. The deposits laid down in this sea indicate nowhere within the area a zone of accentuated subsidence. On the other hand, from the southern border of the Shantung massif to eastern Yunnan, past the Lower Yangtze Valley, central Hunan and central Kuangsi, a pure limestone formation of Middle Carboniferous age stretches out more or less continuously towards the south-west, attaining several hundred metres in thickness in central Kuangsi. This limestone dies out towards the northern part of the Kweichow Plateau, the northern part of Hunan and the western part of Hupeh. Along this line we can definitely trace the north-western margin of the trough. With equal certainty we know that a belt of land on the south-east—Fukien—stood above the Middle Carboniferous waters. There is therefore hardly any doubt as to the continued existence of the southern Palæocathaysian geosyncline essentially along the site where it existed during Silurian-Lower Carboniferous times. Almost precisely in the same terms we can describe the extent of the trough as it existed in the succeeding Uralian epoch.

A remarkable change was brought about at the end of Uralian times, as far as the history of the Palæocathaysian geosyncline is concerned. In Lower Permian times, practically the whole of southern China sank below sea level, including the old land on the south-eastern coast and the Kweichow Plateau, while northern China was permanently lifted above marine water. But Mongolia was temporarily flooded, also for the last time, by the Lower Permian sea. It will be recalled that the northern part of the Palæocathaysian geosyncline was elevated at the end of Ordovician times. And now the lingering geosyncline in the south also disappeared. With the ultimate disappearance of the Palæocathaysian geosyncline, the distribution of the high and low-lying regions became at once impressive and illuminating. The uplift of northern China and the subsidence of southern China are separated by a sharp line of demarcation. This is the line along which the Tsinling Range stands at the present day. The Tethys of Suess should therefore refer strictly to the Permian sea of southern China, for it has nothing to do with the Palæocathaysian geosyncline.

Mesocathaysian Geosyncline

Now we come to deal with the obscure history of the Mesocathaysian geosyncline. The difficulty in elucidating the history of this geosyncline arises from the fact that marine sedimentation during this period plays only an insignificant rôle in China, since a powerful disturbance occurred in the Middle or at the end of the Lower Permian period. The Chinese Tethys was evidently cut off from its western continuation by rising land and by mountains in south-western China; and the lifting of the old land along the south-eastern coast was also in evidence. In late Permian and Triassic times, however, a depression in the south-western part of the country once again supervened, broadly assuming a south-west trend. In this depression, now called the southern part of the Mesocathaysian geosyncline, were laid down the uppermost Permian and the Triassic marine sediments. It is so called because it followed the trend of, and was, in fact, developed on the same site as, the old geosyncline which disappeared at the end of Uralian times.

The northern counterpart of this regenerated geosyncline still requires careful investigation as regards its exact extent. But a relatively narrow trough is known to have come down from the Arctic, past the maritime province of Siberia, and probably joined the Triassic trough in northern Korea. Whether the marine Trias developed in south-western Japan formed a part of the same trough, and whether this northern trough was actually in communication with that running across southern China by way of the present Yellow Sea, are questions that cannot be answered at present. At all events, these features remind us of the general trend of the Palæocathaysian geosyncline, and were likewise developed near the border of the eastern Asiatic Continent. They are therefore to be treated as features of the same class.

So far we have attempted to summarize the historical development of the geosynclines trending north-east as complex and gigantic synclinal folds. We have also recognized land-masses which accompanied these synclinoria. Nothing, however, is definitely known as to the shape of these land-masses beyond the fact that they stretched out side by side with the geosynclines. The surface form of these extinct geanticlines is still ill-understood, and probably can never be fully elucidated, however searching a method we may apply. Their geanticlinal character is arrived at not so much from the structure of their basement which still remains exposed, but rather from a close study, by way of comparison, of modern examples that arose in their place. These successors, so to speak, of the ancient geanticlines are the Neocathaysian geanticlines, which offer far better facilities for close examination.

Neocathaysian Geosynclines and Geanticlines

An inspection of any general map of modern eastern Asia cannot fail to impress us with the striking distribution of land-masses and sea troughs. The festoon islands of Japan represent the emerged parts of a strip of arched land-mass which forms the actual border of the eastern Asiatic Continent. In front of this land-mass, on the Pacific side, runs a foredeep, the deepest part of which is the well-known Tuscarora. On its western side spread the Sea of Japan, the Yellow Sea and the Tunghai, obviously in a geosynclinal form. It seems beyond question that the Japanese Islands constitute the outermost geanticline existing in eastern Asia after the fashion of Palæocathaysia, though much reduced in bulk.

The Yellow Sea and Tunghai have been fed by an enormous quantity of material brought down from the mainland by several mighty rivers. Consequently, the shape of the sea floor, as revealed through soundings, does not indicate the true form of the bottom of the geosynclinal trough. Conditions are otherwise in the Sea of Japan. In this part of the trough the available bathymetric maps suggest generally that the slope of the sea floor is distinctly more gentle on the Japanese side and much steeper on the side of the mainland, namely, in front of the Shikotan-Alin Range extending to the north-eastern coast of Korea. Observations on the physiographical development of South Manchuria have tended to show that very slight elevation, if not actual sinking, has taken place in recent times on its western side along the border of the Liaoho Valley. But more notable elevation is reported to be recorded by raised beaches and river terraces along the South Manchurian coast as we trace them towards the east. Scanty as the relevant data are, it appears not unreasonable to regard the

Shikotan-Alin region, the South-Eastern Highlands of Manchuria, the Liaotung Peninsula, and perhaps the Shantung massif, including the peninsular area, as another modern geanticline which tends to become steeper in its eastern wing as does the Japanese geanticline. The Uplands of South-Eastern China form another geanticline equivalent to, though probably not in continuation with, the northern one.

It has been pointed out that the Sea of Japan, the Yellow Sea and the Tunghai constitute a single geosyncline, which may be appropriately called the outer Neocathaysian geosyncline. Now we come to consider the inner Neocathaysian geosyncline. This is an extensive trough running obliquely across China from northern Manchuria to the Central Yangtze province. Only a minor part of this geosyncline is submerged at present, forming the Gulf of Peichihli or Puhai. In the North China Plain the sediments in the geosyncline probably amount to many thousands of feet in thickness. Apart from the superficial cover, nothing is known about them at present. Borings put down at Tientsin have proved the existence of fresh-water deposits reaching a depth of over 500 feet below present sea level. On the other hand, rejuvenation of some of the rivers as they run down from the hilly land of western Peiping indicates a relative elevation along that mountain zone. Such positive evidence as this serves to dispel any doubt as to the active growth of that part of the geosyncline and its accompanying geanticline on the west. Facts of this kind are to be looked for all along the Sungari-Liaoho Valley, the North China Plain and the Central Yangtze Basin. For the present these depressions are regarded as a single geosynclinal feature on the ground that they all fall into line, and that each of them faces, on its western side, a bold front of powerful mountain ranges, having the same general trend, namely north-north-east. It is hardly necessary to add that the inner Neocathaysian geosyncline is precisely of the same trend as the outer geosyncline and the Japanese geanticline.

The mountain ranges on the western side of the inner Neocathaysian geosyncline stand as the last geanticline of the series towards the inland. This feature is remarkably simple, but none the less striking. It consists of the Great Khingan, the Taihang, the Gorge Mountains of the Yangtze, the eastern border of the Kweichow Plateau and probably the Yaoshan in Kuangsi. Were it not for the interruption of the mighty east-west mountain zones these ranges would have obviously formed a continuous line of disturbance. In his synthetic interpretation of the more salient structural features of China, von Richthofen clearly recognized the homologous nature of the Great Khingan and the Taihang Ranges, but he failed to see their continuation farther to the south-west.

Attention has been called to the recent sinking, at least in the northern part, of the inner Neocathaysian geosyncline, accompanied by rising on the part of the geanticline standing on the west. This does not imply that these features only began to grow in recent times. They have a much older history. In the Manchurian Plain undisturbed beds, with ganoid fish belonging to the Pholadophoridæ, mark the development of the geosyncline already in the Cretaceous period. The presence of folded Lower Cretaceous shales, more than 500 m. thick, in the Nengkiang (Nonni) Valley, shows that the northern end of the geosyncline has been subjected to disturbance in Upper Cretaceous or post-Cretaceous times. In the Central Yangtze Basin red sandstones and shales with beds of gypsum attain a considerable thickness in places. In northern Hupeh the gypsum beds are mined; and in central Hsinan these gypseous red beds contain fossil fishes. It is highly probable that they belong to the Cretaceous. Thus, both in the northern and southern part of the Neocathaysian geosyncline, we have evidence for the development of an inland basin in Cretaceous times. It seems beyond question that Cretaceous sediments will be met with if we bore deeply enough in the North China Plain. Exploration in that plain, say by seismic methods, will possibly reveal the presence of deposits of economic importance. Even more convincing is the evidence of mighty Jurassic and Cretaceous movements along the geanticline standing on the western side of this geosyncline.

THE GREAT KHINGAN RANGE

The northernmost part of the geanticline, namely, the Great Khingan, lies between the Mongolian Plateau on the north-west and the Manchurian Plain on the south-east. As far as is known, the structure of the whole range is wonder-

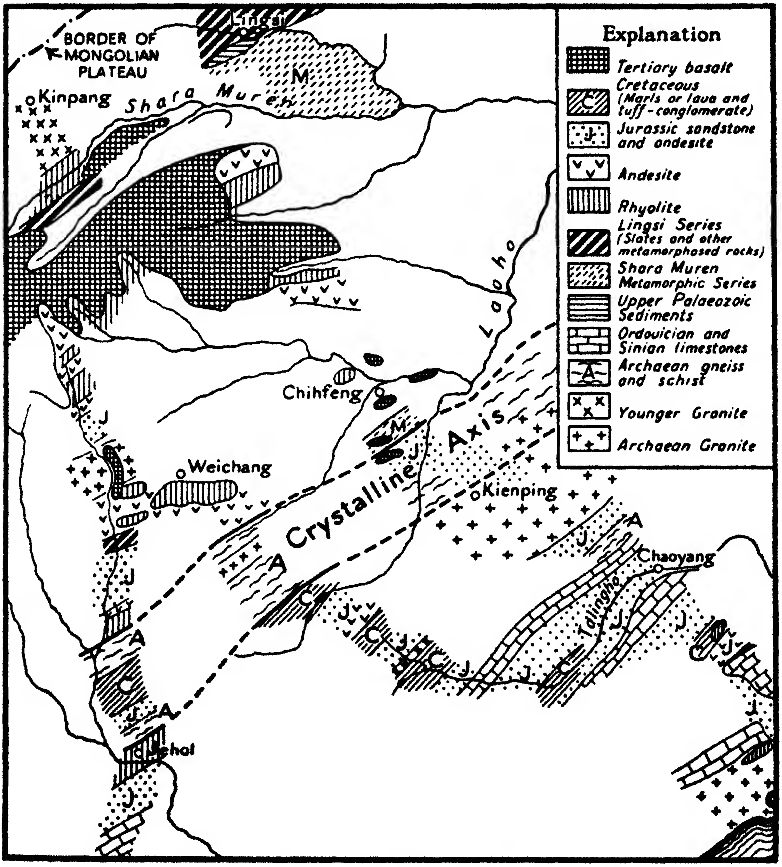

FIG. 62. A sketch map showing the structure of the southern Great Khingan Range. (After H. C. TAN and TEILHARD DE CHARDIN.)

fully uniform. It appears to consist of three broad zones, the western, central and eastern, with a "crystalline barrier" running between the western and central zones. The western zone shares some of the characteristic features of the Mongolian Plateau with which it is in immediate contact.

In this zone Sinian and Ordovician strata are absent; upper Palæozoic and lower Mesozoic rocks are present but in a metamorphosed state; acid eruptives predominate; tension rather than folding is indicated by the occurrence of numerous, caterpillar-like dykes which follow the north-east strike of the country rock. In the famous Weichang-Kinpang district, southern Khingan, Teilhard de Chardin recognized two phases of Mesozoic igneous activity, the earlier phase characterized by andesite, and the later by rhyolite. The latter contains an unusual quantity of crystals of fluorite. The igneous complex, together with its associated green sandstones, conglomerates and arkose sandstones, was reduced to a peneplain on which spreads an extensive sheet of slightly tilted basalt. Intercalated in the basalt are now and then layers of fine sand and silt, in which occur plant remains probably belonging to the Upper Miocene. The basalt was evidently poured out along the very edge of the Mongolian Plateau, and flowed along the gentle slope on the east.

In the western zone of the northern Khingan similar Tertiary basaltic flows have not been observed. The Mesozoic volcanic series, consisting of trachyte, rhyolite, andesite and tuffs, and more than 1,000 m. thick, covers, however, a wide area of the Chalainor and Dalainor districts immediately behind the Great Khingan front. They are involved in the formation of the Bargo Highland as well as the Chalainor-Dalainor Basin. In the north-western part of the basin they generally strike north-north-east and dip south-south-east at an angle varying from 20° to 40°. A large area of intrusive porphyry is also mapped by T. F. Hou between Chalainor and Manchuli. According to Hou, the volcanic series is to be correlated with the Lower Cretaceous of similar lithological type in the Nonni Valley and in Transbaikalia. Within the basin, the volcanic series is concordantly overlain by a coal-bearing series either of Upper Cretaceous or early Tertiary age. The presence of pebbles of andesite and rhyolite in the coal-bearing series shows an interval of erosion consequent to an important movement between the Lower Cretaceous and the coal-forming epoch.

The crystalline barrier, as described by Teilhard de Chardin, forms a distinct zone of tectonic importance on the western side of the upper Laoho Valley, to the south-west of Weichang. The crystalline rocks begin with a mighty series of amphibolite, followed by mica-schists, gneisses and " laminated " porphyritic granite, all striking north-east. A little further to the north-east, Tan maps a broad exposure of schists often intruded by pegmatite. The schist is sometimes so rich in mica and hornblende that it may be called mica- or hornblende-schist, reminding us of the amphibolite mentioned by Teilhard de Chardin. Locally these rocks contain auriferous quartz veins. They form hill-ranges in the northern part of Kienping approximately along the same strike as that of Teilhard's crystalline barrier. Judged from Tan's map, these ancient schists and gneisses are by no means restricted to that zone. They are widely exposed to the north-west of the Tachingshan, north-west of Chaoyang. In the northern part of the Khingan it is not definitely known whether this crystalline axis persists.

The central zone is characterized, according to Teilhard de Chardin, by a powerful development of non-metamorphosed Sinian and Ordovician limestones, Jurassic green sandstones and conglomerates with interbedded andesitic flows, and Cretaceous white marl or shale with *Lycoptera*. Tan, however, divides the Mesozoic formation in the southern Khingan into several series. He mentions a red sandstone, exposed in the south-eastern part of the Peipiao coalfield, and lying in direct contact with the Sinian, as being probably of Triassic age. The Jurassic is said to be represented by the Hsinlungkou Volcanic Series consisting of andesitic tuff and tuff-conglomerate in the lower part, and of a coal-bearing series in the upper part, chiefly composed of greenish and yellowish shales and sandstones amounting to about 100 m. in thickness. Then comes the Chihfeng Series in upward succession; but it is separated from the Jurassic by a pronounced unconformity. This series is variable in lithological character and thickness, being largely composed of yellow and green clay-shales and sandstones with poor coal seams. A characteristic white marl seems to be usually present. The *Lycoptera*-bearing white marl of Teilhard de Chardin almost certainly belongs to the same formation. Fresh-water shells, insects and plants found by Tan in this series prove its Cretaceous age. The thickness of this series varies from 200 m. to 700 m. Finally, Tan describes the Chaoyang Series, upwards of 1,000 m. thick, and consisting essentially of tuff-conglomerate, agglomerate and contemporaneous lava flows, with workable seams of coal in the lower part, together with plant remains of Cretaceous, probably Upper Cretaceous, age. Thus the green sandstones and conglomerates referred by Teilhard de Chardin to the Jurassic may turn out to be of Cretaceous age, at least in part.

Eruptive rocks, though still important members in the central zone, play a distinctly less prominent part than the sediments. The more "competent" members of the rocks involved in this zone, such as the Sinian and Ordovician strata, are repeatedly thrust upon the softer Mesozoic series from the north-west, forming a long series of large-scale *schuppen*. Along the plane of thrust is often developed a zone of mylonite, accompanied here and there by igneous outpourings. Tan is inclined to believe that all these fractures were normal faults. The structure of the Peipiao district, as discussed by W. H. Wong, seems, however, to demonstrate fairly conclusively the importance of lateral pressure applied to the Khingan Range in connection with its uplift.

While these structural relations are actually observed in the southern part of the Great Khingan, their extension towards the northern part of the same range may be inferred from the observations made by E. Ahnert along the Siberian railway. A series of green sandstones and slates, together with conglomerates, are packed in endless bands, all striking north-east. As in the southern part of the range, these bands are invaded by numerous acid dykes. Teilhard de Chardin, who hurried across this part of the range, identified these rocks with his Lingsi Series developed further south-west. He has even recognized in Barim and the Niangtzeshan individual dykes that were found in the

Lingsi district. The French observer goes on to emphasize the parallelism of development by pointing out the occurrence of small patches of a metamorphosed limestone with crinoidal stems at Kharko, west of Erekte, near Chalainor, as equivalent to similar occurrences in Soron, middle Khingan, and in the south-western part of the same range. This thin marine deposit is believed to be of Permian age.

The eastern zone is characterized, according to Teilhard de Chardin, by Mesozoic intrusive granite and strongly marmorized Sinian limestone. It is "partially sunk under the sea at Hulutao, but recognizable along the line running from Tahushan to Mukden, Kirin and further north across Manchuria." This lowland zone obviously belongs to the inner Neocathaysian geosyncline, whatever might be its earliest history. It represents the foreland of the Great Khingan rather than a part of the Khingan itself.

Summarizing the evidence, we may conclude that the Great Khingan comprises a zone of intense tectonic disturbance running, as a whole, from north-north-east to south-south-west. Volcanic activity began in Lower Jurassic times with repeated outpourings of andesitic lava. After intervals of quiescence, the process culminated in Upper Cretaceous times. During this period of mountain-building movement Mongolia persistently pressed south-eastward, producing numerous fractures along the Khingan front. Some of these fractures were immediately filled up by magmatic injections which are largely of acid composition. The plateau basalt did not arrive until the closing stage of the Miocene. Acute folding and thrusting undoubtedly began in the Jurassic and were essentially accomplished in the latter part of Cretaceous times. Simultaneous with the growth of this anticlinorium was that of the synclinorium on the east.

The Luliang and Taihang Ranges

It will be recalled that a belt of ancient crystalline rocks appears between the western and central zones of the Great Khingan, and that the central zone is characterized by a powerful development of Sinian and Ordovician strata and tuffaceous deposits of Mesozoic age with contemporaneous

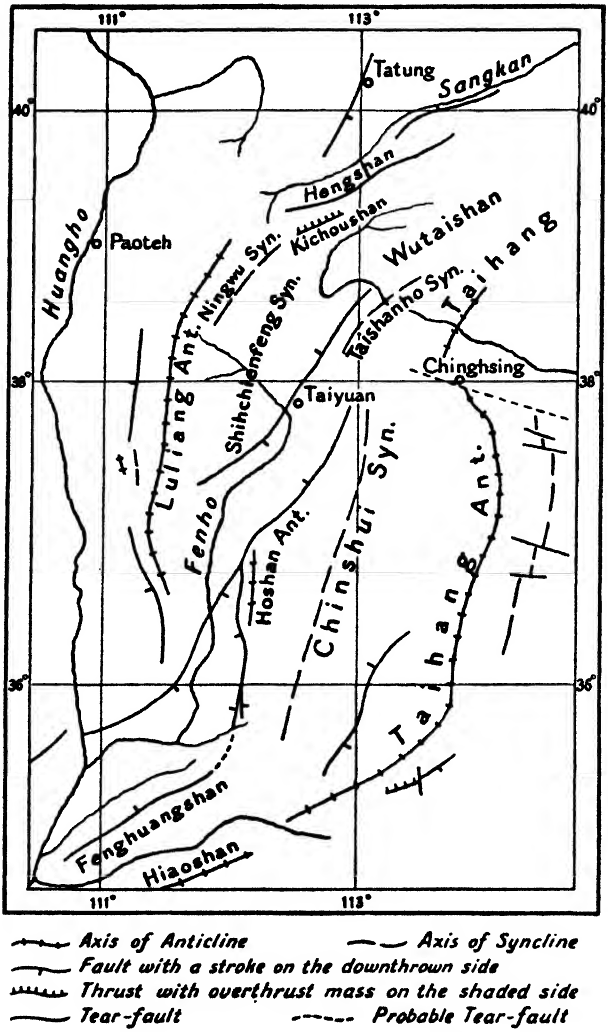

FIG. 63. A tectonic map of Shansi showing the major structural features of the Shansi geanticline and tear-faults on the eastern side of the Taihang Range, the structure of the coalfields on the eastern side of the Taihang being simplified, and the lateral displacement due to tear slightly exaggerated. (Largely adapted from C. C. WANG.)

lava flows. In spite of the interruption of east-west mountain ranges standing on the southern border of Jehol and northern Hopei, this axial zone of ancient rocks, consisting of more gneisses than schists, continues to run to the south-west, past the Hsuanhua, Cholu and Huailai districts in north-western Hopei, and then swells up together with the Wutai rocks to form lofty mountains of the Hengshan and Wutaishan in northern Shansi. Further south-west they subside for some distance, but reappear in the Luliang Range running continuously for 330 km. in a south-south-west direction.

East of the Wutai-Luliang line a mighty sequence of Sinian and Lower Palæozoic strata, chiefly limestones, is broadly folded and repeatedly faulted, forming the Shansi Plateau. The Mesozoic volcanic series, which plays an important rôle in the central zone of the Khingan, is only developed in the north-eastern part of this area, being represented by the Chiulungshan and Tiaochishan Series of the Western Hills of Peking. They are likewise invaded by granite bodies. Towards the south-west, the Palæozoic coal-bearing series and its overlying barren sandstones take their place. The Western Hills of Peking and the Shansi Plateau may therefore be regarded as equivalent to the central zone of the Great Khingan. Although folding is far less prominent and thrusts are not actually observed in the Shansi Plateau, evidence can be adduced to show that this zone of broad folding was likewise subjected to lateral pressure at about the same time as the Khingan was uplifted.

The Shansi Plateau is generally understood as a region consisting of shattered blocks due to normal faulting. This is largely true as far as the faults are concerned. Along the western side of the Luliang Range C. C. Wang maps two large faults, the Shihmen and Linghsien faults, running parallel to the range, with downthrow to the west. Another fault of considerable extension is indicated on Wang's map on the south-eastern side of the Hengshan, with downthrow to the north-west. More remarkable is a pair of faults running across the central part of the plateau in a south-westerly direction. Both of these are, according to Wang, of the pivoted type, with their downthrow on the north-western side in the north-eastern part, and on the south-eastern side in the south-western part. One of these faults passes the neighbourhood of the city of Taiyuan, with that place as the pivot, and the other extends along the western side of the Hoshan and the north-western border of the Pingyang Plain. This latter is joined at its pivot by the Hoshan Fault, which probably continues to run south-westward to join the Fenghuangshan fault along the north-western foot of that mountain. The central depression in the Shansi Plateau is largely determined by the three last-named faults.

Important as these faults are in determining the block structure of Shansi, there remains another phase of the tectonic problem which requires careful consideration. The Luliang anticline represents a zone of strong folding; for the Cambro-Ordovician, as well as the Carboniferous and Permian strata, dip away from both sides of the mountain range at an angle varying from 30° to 50°. Along the eastern edge of the western block, that is, on the western side of the Fenho Valley, the Ordovician limestone sometimes stands on end, if not actually reversed, *e.g.*, at the pass leading to the Tungtayao coalfield. On the other hand, the beds in the eastern block only dip gently towards the plain in the neighbourhood of Taiyuan. As far as that part of the central basin is concerned, the structure is obviously an asymmetrical syncline, which forms the Taiyuan Plain, with the steep anticlinal limb tending to override its western part and with a gentle swell forming the eastern hills. Further south this structural relation is apparently rendered less clear by the development of mighty faults. The Luliang anticline is bordered on its western side by more folds, and on its north-eastern and eastern side by the Ningwu syncline, Wutaishan anticline, Taishanho syncline, Hoshan anticline, Chinshui syncline and the Taihang anticline. The axes of these folds strike north-north-east in the south-eastern part of the province. In the marginal part of the Ningwu syncline the strata dip at an angle averaging 40°. Overthrusts to the south-east were actually observed in the Kichoushan, south-east of the Ningwu Basin. In the Hoshan anticline, which forms the south-eastern border of the Fenho Valley, the beds dip at about 10° towards the east and at about 30° to the west.

Largest of all are the Chinshui syncline and the Taihang anticline. The former forms the south-eastern plateau of Shansi, with gently inclined beds of Triassic sandstones and shales occupying the central part of the raised and elongated basin; and the latter, the Taihang anticline, defines the eastern boundary of the geanticline or the eastern border of the Shansi Plateau. Archæan, and in some cases the Wutai, rocks form the core of the anticline, which is rather extensively exposed in the northern part of the Taihang Range between the Western Hills of Peking and the mountains to the north of the Hutoho Valley. The Archæan gneiss in the Tzechingkuan area between Yihsien and Laiyuanhsien is overlain by Sinian limestone, which in turn is overlain by Ordovician limestone and Carboniferous shales, and the latter are invaded by a young granite associated with tuffaceous sandstones. The development as a whole is still essentially of the same type as that of the Western Hills of Peking and of the Great Khingan further north. The rocks generally strike north-north-east. South-west of the Tzechingkuan district the Archæan exposure appears to be still broader, but becomes buried in the area where the Taihang suddenly turns to the south. A limited exposure of schist and quartzite appears in the north-western corner of the Chinghsing coalfield, associated with the line of disturbance usually regarded as a normal fault on the western side of that coalfield. Judged, however, from the highly disturbed state of the western part of the coalfield, the fault seems to be a reversed one, if not an actual overthrust from the west.

Southward, these schists and quartzites reappear in the Lingcheng and Neichu districts. But there they are displaced for a considerable distance to the east, as compared with the exposure in the Chinghsing district. In general, the farther south we go along the Taihang Range the more important become the Palæozoic formations. Restricted inliers of gneisses and schists occur in or near the axis of the anticline in north-western Wuan and to the west of Linghsien. Isolated small patches of andesite are also found in these districts. These metamorphic and igneous rocks are apparently the last vestiges of the Archæan and Mesozoic volcanic series towards the southern part of the Taihang Range. The granitoid intrusion in the Lingmingkuan district and the diorite mass in the Wuan area are among the few intrusive bodies found in the southern Taihang. Insignificant as these igneous rocks appear to be, they represent similar phases of igneous activity to those which play such an important part in the Great Khingan and the northern part of the Taihang.

The detailed structure of the main range of the Taihang, which mainly consists of masses of Ordovician limestone, has not yet been worked out. The structure of the coalfields fringing the eastern and south-eastern flank of the range is, however, known to some extent, and throws light upon the question of earth movement. The data collected by different observers are admirably summarized by T. F. Hou. The coalfields are determined by large longitudinal faults, which generally run north-north-east in the middle part of the range, and north-east in the southern part. In places shallow synclines are formed, following the same trend as the axis of the Taihang anticline. These longitudinal strips of coal-bearing rocks are subdivided by small anticlines with their axes running nearly perpendicular to the Taihang anticline, and they are accompanied by faults which are parallel to the axes of the transverse anticlines. A point of great importance and interest is that some of these transverse faults, *e.g.*, the Shaho fault in the Lingcheng coalfield, and the Huyu fault in the south-eastern part of the Wuan district, tear and displace the coal seams for a horizontal distance of more than 6 km. Many more tear-faults of lesser magnitude are present. They all indicate lateral pressure from the Taihang anticline. In the Chiaotso coalfield, northern Honan, the boundary fault between the Ordovician limestone on the north-western or Taihang side is actually reversed on the western side of the Fenghuangling anticline.

These tear-faults, together with the folds and occasionally observed thrusts in the Shansi Plateau, demonstrate beyond doubt the intensity of lateral pressure engaged in bringing about the Luliang-Taihang anticlinorial complex. Strata ranging from the Sinian to the Jurassic coal-bearing series are all harmoniously folded. Cretaceous deposits are meagre and often wanting. C. C. Wang, who mapped the whole area, reports, however, one instance in the Hunyuan district, north-eastern Shansi, where the Upper Cretaceous lies unconformably upon the older strata. This would seem to fix the date of folding at the end of the Jurassic or before the commencement of Upper Cretaceous times. Some of the faults, especially those forming the boundaries of the coalfields on the eastern side of the Taihang Range, are probably features associated with, but consequent on, the uplift as a result of the release of lateral pressure. But others were obviously developed in Tertiary times. In the Yuanchu Basin, southern Shansi, the Eocene conglomerate stands high on the plateau. Deposits of that kind could not have been formed under the present topographical conditions. The Kichoushan fault cuts off the overthrust strata; and the Taiku fault, which forms a prominent scarp on the south-eastern side of the Taiyuan Basin, was still in active growth in post-Pliocene time. Thus we may say that folding in the Shansi Plateau was largely accomplished in late Mesozoic times by lateral pressure, which also contributed to the formation of the Great Khingan during the same period.

The Gorge Mountains of the Yangtze and the Eastern Kweichow Plateau

This region of unusual geological interest is still comparatively little known. Apart from a few observations made in Kweichow, all investigations have been concentrated in the Gorge area. Sufficient data, however, have been brought to light to warrant our belief that this tectonic zone in central China is practically a continuation of the

Luliang-Taihang anticlinorium of the north, notwithstanding the fact that they are separated by the mighty Tsinling Range.

As we pass from the Red Basin of Szechuan, fold after fold of Mesozoic as well as Palæozoic strata is cleanly cut across by the Yangtze River. Most of the major folds strike north-east, but a few east-west. Before finally emerging from the gorges the Great River forces its way across the strike of the Huangling anticline, in the core of which are exposed schists and gneisses, probably of Archæan age, pre-Sinian granite and Sinian strata. These are succeeded, on the western side of the anticline, by a long series of Palæozoic and Mesozoic rocks, none of them showing any notable discordance in stratification. On the eastern side of the anticline is developed a red sandstone, the Tunghu Sandstone, resting with a massive basal conglomerate upon a deeply-weathered surface of Ordovician limestone. The age of this sandstone has given rise to some discussion as to whether it belongs to the Cretaceous or early Tertiary. In any case, this occurrence enables us to determine that the date of important folding in the Gorge area was between the end of the Jurassic and the beginning of Tertiary times. Such a movement can be paralleled with one of the phases of late Mesozoic movements in the Great Khingan and the Luliang and Taihang Ranges. Nor is this folding the last episode of earth movement in the Gorge area; for the Tunghu Sandstone itself forms a syncline on the eastern side of the Huangling anticline.

On the western side of the Yangtze Gorge anticlinorium, a series of pinched folds, all having a north-easterly trend, are spread out from the Gorge Mountains to the interior of the Red Basin of Szechuan. The oldest formation exposed in the core of these anticlinal folds is the Chialing Dolomite of Triassic age. In some places the Chialing Dolomite is actually overthrust, showing the prevalence of considerable lateral pressure in connection with the development of the folds within the Basin. On the flanks of the anticlinal hills the younger beds dip away from the hill with a gradual decrease in the amount of dip until we come to the intervening plain, where the Cretaceous sandstones and shales lie almost flat. No marked discordance between any of the succeeding beds can be observed. The conclusion to be drawn from this state of affairs is either that sharp, localized folding took place towards the end of the Cretaceous, or that folding began in that part of the Red Basin before the Cretaceous and proceeded more or less continuously as deposition went on.

The Huangling anticline pitches toward the north-east and south-west. It is in fact an elongated dome turned to the north in its north-eastern part. From the point of view of the geanticlinal structure we might expect that the anticlinal axis continues to run to the south-west. As a matter of fact, this is not the case. The dome structure ends at a little distance on the southern side of the river. It is followed southward by a series of anticlines and synclines, which involve the Sinian and Palæozoic strata, with their axes running nearly east-west, and tending to bend round towards the east-south-east as they stretch to the Itu and Chihkiang districts on the southern side of the Yangtze. The more important ones among this series of folds are the Changyang anticline and the Maanshan-Hofeng syncline. The former is overturned to the north; and its axis points to the north of west, extending between the city of Changyang and the neighbourhood of Ssutuho. The Maanshan-Hofeng syncline runs westward for some distance from the west of Itu, and gradually bends to the south-west past Tzechu and Hofeng, where the syncline, involving the Patung Series of Triassic age, exhibits a distinct south-west trend. More anticlines and synclines in the form of elongated domes and basins are developed in the eastern part of south-western Hupeh. They generally follow the above-described features as regards trend.

In the western part of south-western Hupeh the folds generally strike south-west, as in the eastern part of the area. The individual folds seem to be arranged *en échelon.* A syncline belonging to this series of *en échelon* folds appears between Kienshih and Shihnan, another between Shihnan and Hsuanan, and a third to the north-east of Laifeng is partially buried by red beds which undoubtedly belong to the Tunghu Sandstone. All the formations older than the Tunghu are, according to C. Y. Hsieh and C. C. Liu, harmoniously folded throughout the area. The main phase of folding must have therefore occurred before the deposition of the Tunghu Sandstone, as in the Gorge district.

The varied nature of the structural trend in south-western Hupeh is comprehensibly summarized by Hsieh and Liu in a tectonic map. If we connect together these local observations, it becomes obvious that the anticlines and synclines, including local elongated domes and basins, form a curved arrangement. In the northern part of the area they generally strike east by south, bending round gradually to the south-west as they proceed towards the west and the south-west. These curved structural axes with a slightly convex front to the north are not restricted to the southern side of the Yangtze Gorges, but are developed, on an even much larger scale, to the north-west of the Huangling anticline. They do not belong to the geanticlinal structure, but are features induced in connection with the development of the Yunnan arc, to which reference will be made later. The normal structural trend of the geanticline, namely, north-east, is resumed in the southern part of south-western Hupeh and in north-eastern Kweichow.

In the heart of the Kweichow Plateau, T. K. Huang observed a belt of the Chihsia Limestone of Lower Permian age thrust, from the west-north-west, upon Cretaceous shales comparable with the Tzuliuching Series of the Red Basin of Szechuan. The overthrust mass forms the Chienlingshan, near Kweiyang, and it runs in a north-north-east and south-south-west direction for a considerable distance. Similar compressive features are expected to occur towards the eastern border of the Kweichow Plateau. As a whole, the structure of that plateau appears to be fairly simple. The farther north-east we go from Kweiyang the older are the beds exposed. Quartzites of Sinian age are already laid bare nearly half-way between Kweiyang and the eastern border of the plateau. On the other hand, the foothills on the eastern side of the plateau are largely composed of Palæozoic limestones. It would thus seem that an anticlinorium, comparable in size with the Shansi anticlinorium, characterizes the structure of the eastern part of the Kweichow Plateau. Like its northern equivalent, this structural complex was involved in, if not brought about for the first time by, one of the late Mesozoic movements.

On the south-eastern side of the Kweichow Plateau extensive anticlines and synclines occur in the mid-western and south-western parts of Hunan. They generally run south-south-west and are particularly well-developed between the districts of Paoching and Hengyang. Further south-west these south-south-west directrices penetrate into the eastern part of the middle Nanling. The major folds form long ranges, such as the Tientsenshan and Huangmaoling to the west of the Wukang and Chengpuh districts, and the Yunshan Range to the east of these districts. In these ranges the Palæozoic and Triassic formations all strike south-south-west, but they are cross-folded in the Nanling. On the southern side of the middle Nanling these Neocathaysian folds are suppressed for a distance, but they reappear in the Yaoshan Range, eastern Kuangsi. It is believed that folds of similar trend are again developed in the Yunkaitashan forming the south-eastern boundary of Kuangsi.

After a survey of the foregoing evidence as to the type of structure of the several tectonic zones, and as to the movement or movements by which they were brought about, it seems difficult to deny the homologous nature of the Great Khingan, the Shansi anticlinorium, the Gorge Mountains of the Yangtze, the eastern Kweichow Plateau and the Yaoshan Range in Kuangsi. In the southern part of this enormous geanticline the major folds appear to be arranged *en échelon.* After noting these similarities, it would be unjust to leave out the differences. The Great Khingan reveals the most violent type of disturbance accompanied by abundant igneous intrusion and extrusion. In the northern part of the Luliang-Taihang zone these activities begin to decline in intensity. The igneous rocks alone make a dwindling display so far as the Mesozoic is concerned, and the Palæozoic sediments play an increasingly important rôle towards the southern part of the same zone. Finally, in the Gorge-Kweichow zone Palæozoic as well as Mesozoic sediments become much thicker, and Mesozoic igneous activity is entirely unknown. Minor intrusions are, however, widespread in the Central Yangtze Basin, giving rise to ore deposits when they come into contact with the limestones—a process comparable with the marmorization of the Sinian limestone, which is due to intrusive Mesozoic granite and which is characteristic of the eastern zone of the Great Khingan.

It is precisely these differences that throw further light upon the similarity of the regional movements which gave rise to the several geanticlinal zones. The decreasing igneous display towards the south can be explained partly by the increasing thickness of the sedimentary cover in the same direction, and partly by the decrease of the intensity of disturbance in the successive zones on which pressure was brought to bear. The question may then be asked: Is it due to the more competent nature of the beds in the zone which is itself less disturbed, or due to diminution of the pressure which was transmitted by a less competent block? The first part of our question cannot be effectively answered from field evidence, but as to the comparative competence of the blocks on the west or north-west part of the deformed zones there is good evidence upon which to form a judgment. The structure of the Mongolian Plateau with its huge bathylith shows that it had already grown as an indurated shield in Jurassic times. It was no longer capable of semi-plastic folding after that period. And certainly no longitudinal folding of any importance has occurred since that time. Consequently when it exerted its pressure in Cretaceous times, the deformation was localized along its south-eastern front, namely, the Khingan Range.

On the contrary, the Luliang-Taihang Ranges are not only broader as a deformed zone, but are relayed by another longitudinal zone of weakness between the Ninghsia Plain and the Shensi Basin. This is the Lungshan and Alashan zone of folding. Similarly, the Sikang Ranges offer a belt of weakness which shared the lateral pressure of the Red Basin of Szechuan with the Gorge Mountains and the eastern

Kweichow Plateau. Moreover, the Red Basin itself is not so resistant a block as the Shensi Basin, for even the Triassic limestone in the Red Basin is often sharply folded. The difference in the intensity of deformation in the several parts of the geanticline under discussion is therefore to be attributed, at least in part, to the competence of the strata which form the several blocks on the north-west. This brings us to an important point, namely, that the movements which occurred in the geanticlinal zone are not confined to that zone, but are connected with a much wider horizontal movement covering large land-masses standing near by. The issue involved will be rendered more obvious when we come to deal with the shear-forms and the mechanism of earth-movement.

The Liaotung-Shantung Massif

South Manchuria and Shantung, though separated by water at present, must be considered from the geological point of view as a single unit. Their relationship is not only revealed in their early stratigraphical development, but in their structural setting. Throughout Sinian and Lower Palæozoic times the western parts of these massifs were involved in the Palæocathaysian geosyncline. Consequently Sinian-Ordovician beds of marine origin are restricted to that part of the area. The eroded surface of the Ordovician limestone is generally covered by Carboniferous and Permian strata, in which thin beds of marine limestones only occasionally occur, and they are nearly everywhere concordant. The Permian sandstones are in turn concordantly overlain by a red sandstone of Triassic age, which is better developed in western Shantung than in South Manchuria. Then comes the Lower Jurassic continental series still concordant with the older beds in western Shantung, but overlapping towards the east, *e.g.*, in the Fangtze district near Weihsien. Presumably this basin of deposition formed an extension of the incipient Neocathaysian geosyncline. Its margin retreated towards the north-west in middle Jurassic times, but continued to occupy the Poshan, Tzuchuan, Changchiu and Tsinan districts in north-western Shantung until the end of the Jurassic. Towards the north this depression probably extended into the western part of South Manchuria, but its eastern boundary is unknown.

In Lower Cretaceous times, two separate basins of deposition were developed in Shantung, one on the east and the other on the west of a land barrier, which continued from a northern land-mass, then probably existing to the north of, and including, the Tsinan, Changchiu, Tzuchuan, Poshan, Itu, Changlo and Weihsien districts in the northern part of the massif. This land barrier extended south-south-westward between the Linchu, Yishui and Linyi districts on the west and the Laiyang, Anchin and Chuhsien districts on the east. The ridge which thus came into existence gradually became buried for a time by the expanding Cretaceous deposit, but a broad stretch of upland was again in evidence in the Upper Cretaceous, having a general north-east trend. At the same time the eastern basin, elongated in the same direction, was deepened, and the margin of the western basin was pushed to the Taian, Laiwu, Mengyin and Linyi districts. The western basin undoubtedly represented a marginal part of the Neocathaysian geosyncline. The intrusion of diorite in this part of the Shantung massif shows the powerful nature of the tectonic stress which gave rise to the deformation in the later part of Cretaceous times. In the eastern basin, the Cretaceous beds are folded to form a syncline extending from the west of Kiaochow to the Chuhsien district. The syncline is rather open and flat in the north-eastern part, but becomes increasingly narrower and compressed towards the south-west. Here is positive evidence of the Shantung massif becoming actually folded towards the end of Cretaceous times. The axis of the fold follows the trend of the Neocathaysian geosyncline. We are therefore justified in considering the Shantung massif as a geanticline on the eastern side of the inner Neocathaysian geosyncline. The continued development of the Neocathaysian geosyncline into South Manchuria leads to the natural inference that the Liaotung Peninsula also forms a part of the same geanticline.

Faults with large displacement were developed in western Shantung and in the Liaotung Peninsula, probably in mid-Tertiary times. In some cases they are associated with basic lava flows. Most of the faults are of the normal type consequent upon uplifting. But in north-western Shantung, *e.g.*, in the Changchiu and Poshan coalfields, the north-south faults are proved to be fractures along which the several blocks are laterally displaced to a distance of 5 to 15 km. Only a small fraction of this distance can be attributed to the effect of normal faulting; horizontal shearing evidently played an important part in those dislocations.

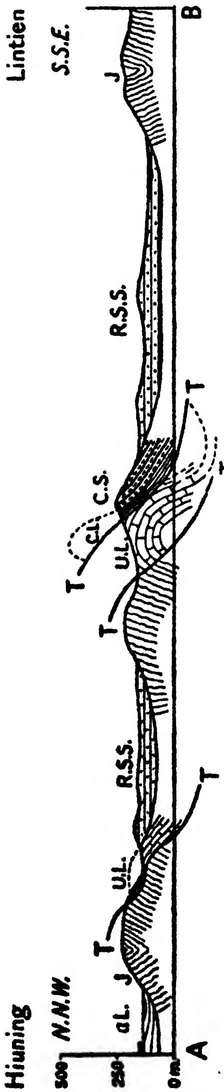

FIG. 64. A section across the north-western border of the South-Eastern Uplands, Southern Anhui. (After Y. Y. LEE.)

U.L. Middle Carboniferous Limestone. J. Jurassic Shale. A.L. Recent Deposit.
C.L. Permian Limestone. R.S.S. Tertiary Red Sandstone. T.T. Thrust.
C.S. Permian Coal Measures.

THE MINCHEH GEANTICLINE

Just as the Liaotung-Shantung massif stands as a geanticline on the eastern side of the northern part of the inner Neocathaysian geosyncline, so the Uplands of South - Eastern China form another geanticline on the eastern side of the southern part of the inner Neocathaysian geosyncline. The region involved in this geanticline, or the Mincheh geanticline, covers the provinces of Chekiang, Fukien and the eastern part of Anhui and Kiangsi. Unlike its northern equivalent, the whole region has been folded and refolded into a series of parallel synclines and anticlines with their axes striking north-east. Faults developed in this region are generally either parallel with or perpendicular to the strike of the folds.

The geanticlinal axis runs along the boundary between Chekiang and Fukien on the one hand, and Anhui and Kiangsi on the other, forming an extensive range called the Shakuanling. Gneisses and schists, probably of Archæan and Wutai ages, are widely exposed along the axis of the geanticline. These ancient rocks are invaded by granite, pegmatite and acid porphyries, largely injected in Mesozoic times. Folds are propagated from both sides of this anticlinorial axis. Consequently it is rather difficult to define the exact boundary of the geanticline. Palæozoic formations are generally harmoniously folded with the Jurassic. The latter is unconformably overlain by the Cretaceous represented by the Kienteh Series and tuff-conglomerate. This is followed by an enormous outpouring of rhyolite, which becomes particularly impressive towards the coastal region. Whatever happened to this geanticlinal region in Palæozoic and early Mesozoic times in the way of tectonic disturbance, it is certain that the existing geanticline was elevated in the later part of the Jurassic period and rejuvenated towards the end of the Cretaceous. Some of the detailed structure of the region will be discussed later in connection with the description of the shear-forms.

Summary

The several broad tectonic features so far discussed are connected with one another (1) by synchronous movements which took place in late Mesozoic times, (2) by a general north-east, or Cathaysian, trend, and (3) by their arrangement in two groups of anticlinoria with a synclinorium in between. Each is, in effect, a complex anticline or syncline developed on a grand scale.

The Great Khingan-Shansi-Kweichow anticlinorium, together with the elongated depression of the Manchurian Plain, the North China Plain, and the Central Yangtze Basin on its eastern side, affords a particularly lucid example of an existing complementary pair of geanticline and geosyncline.

The characteristic feature about the Great Khingan-Shansi-Kweichow geanticline is that it forms the raised front of the Mongolian block and the blocks of the Shensi and the Szechuan Basins, which, in each case, supplied the lateral pressure. None of these uplifted masses is bilaterally symmetrical with reference to its axis; but all of them present a bold front on their eastern side. The shape of the trough on

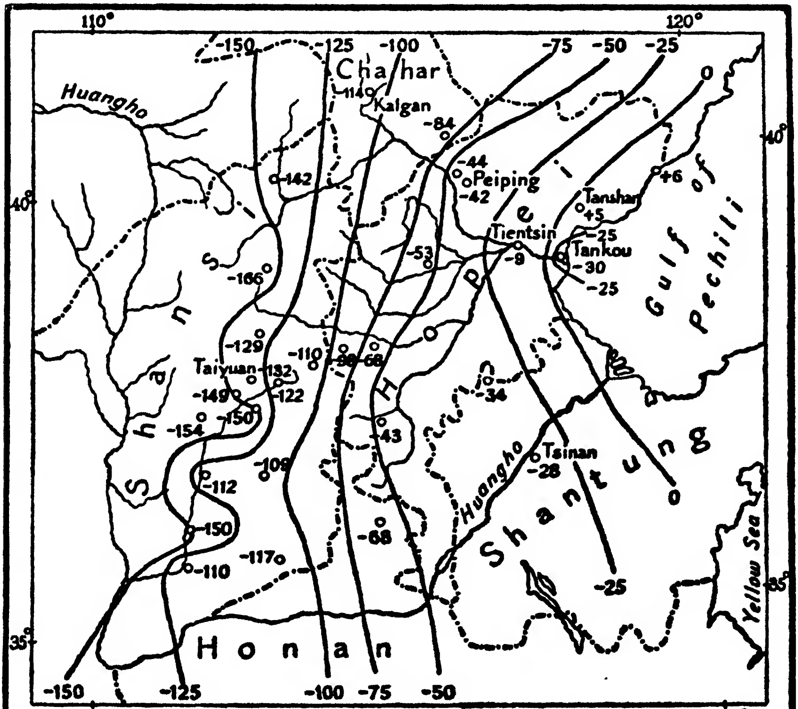

FIG. 65. Isanomales of Northern China. (After R. P. P. LEJAY and LOU JO YU.)

the east is more difficult to determine. Gravimetric survey in northern China discloses the fact, however, that the isanomales are not evenly distributed over the North China Plain, but are more crowded in its western margin. This seems to indicate an asymmetrical form of the trough, with its deeper part located along a line not far removed from the geanticlinal front on the west.

With these modern examples in view, it is natural to infer by analogy that the extinct geosynclines, such as the Palæocathaysian and Mesocathaysian geosynclines, were each accompanied by a geanticline. And in the case of the Palæocathaysian geosyncline its geanticlinal counterpart is known to be Palæocathaysia. The old highland was planed down or subsided. Consequently its former existence is far more difficult to recognize than the geosyncline of which we have sedimentary record. As already pointed out, the zone of maximum subsidence occupies the western part of the Palæocathaysian geosyncline, as may be judged from the comparative thickness of the sediments in different parts of the trough. The Palæocathaysian geosyncline would therefore appear to be also asymmetrical in shape, with its deeper part located nearer to the western margin.

If a geosyncline is a symmetrical trough, as implied in E. Haug's interpretation, then we might consider such a depression as resulting from mere subsidence due to the simple operation of gravity. Since the geosynclines under consideration are asymmetrical, application of lateral pressure is thereby suggested. This, together with the detailed tectonic evidence afforded by the Great Khingan, the eastern flank of the Taihang, and parts of the Kweichow Plateau, leads us to conclude that the Cathaysian geosynclines and geanticlines are a group of compressive features due to a pressure coming from the north-west and a powerful resistance on the south-east.

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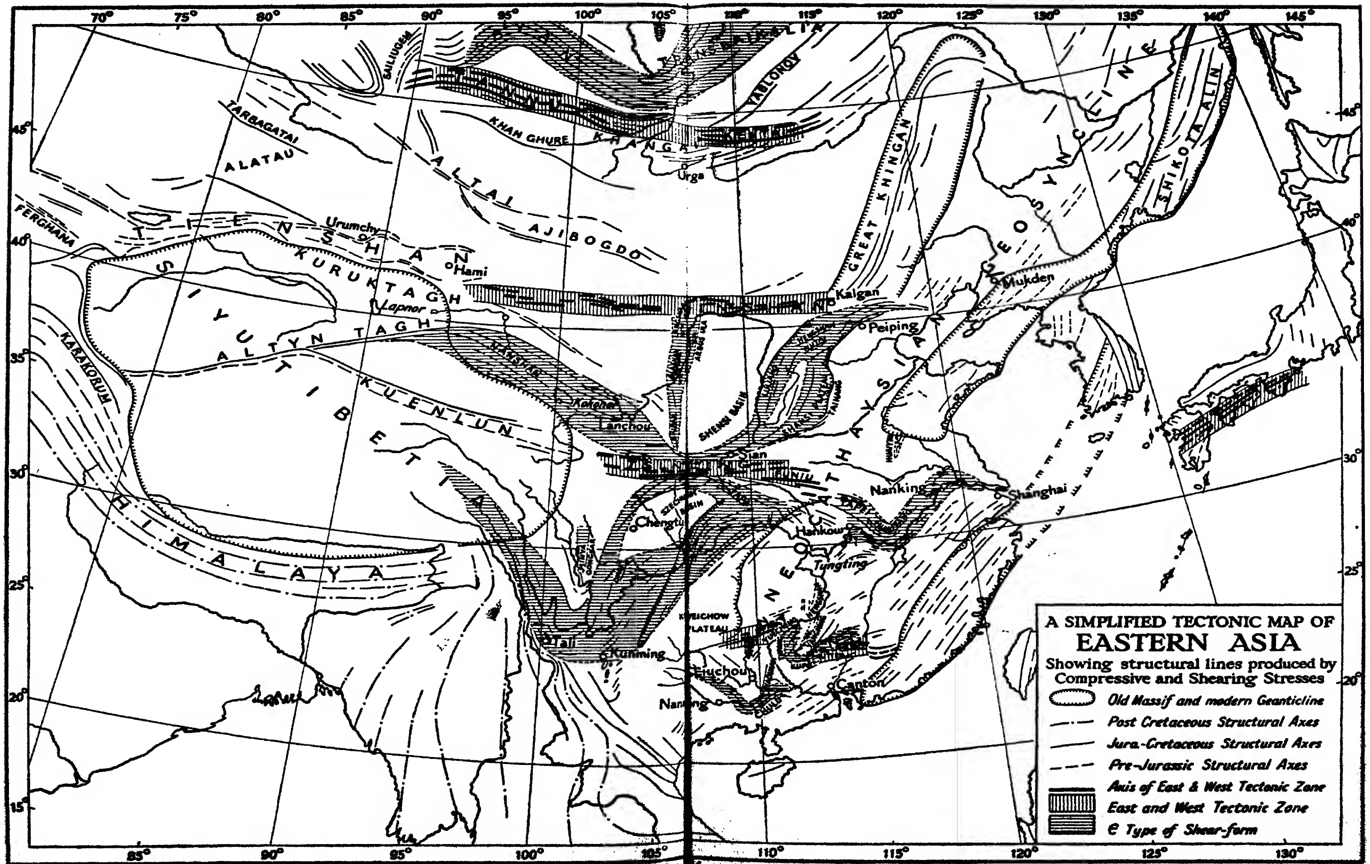
A SIMPLIFIED TECTONIC MAP OF
EASTERN ASIA
Showing structural lines produced by Compressive and Shearing Stresses
Old Massif and modern Geanticline
Post Cretaceous Structural Axes
Jura-Cretaceous Structural Axes
Pre-Jurassic Structural Axes
Axis of East & West Tectonic Zone
East and West Tectonic Zone
Type of Shear-form
TIEN SHAN
KURUKTAGH
ALTYN TAGH
KUENLUN
SIYUTIBETIA
HIMALAYA
KARAKORUM
FERGHANA
ALATAU
TARBAGATAI
ALTAI
AJIBOGDO
KHAN GHURE
KHANGAI
SAILIUGEM
YABLONOY
GREAT KHINGAN
SHIKOTA ALIN
NEOCATHAYSIAN
GEOSYNCLINE
NANSHAN
SHENSI BASIN
SZECHUAN BASIN
KWEICHOW PLATEAU
Urumchy
Hami
Lapnor
Urga
Kalgan
Peiping
Mukden
Lanchou
Kokonor
Sian
Chengtu
Hankow
Tungting
Nanking
Shanghai
Tali
Kunming
Kweichou
Nanning
Canton

FIG. 6.

CHAPTER VI

EAST-WEST TECTONIC ZONES

THE Cathaysian geosynclines and geanticlines are, as we have noted, interrupted at regular intervals by another group of features which run nearly east and west. In fact, the whole of the eastern Asiatic continent is divided into latitudinal segments by these east and west fold-zones. The geological history of the eastern Asiatic mainland, as far as is known, clearly records the prolonged existence of these zones. Some, if not all of them, date back to Sinian times, and have gone through a series of modifications, but have stoutly held their general trend and position. We can hardly deny the independent nature of their existence if we consider their history in comparison with other tectonic features. This does not, however, mean to imply that they never interfere with, nor are themselves ever interfered with by, other structural lines. On the contrary, it is through their interference with the Cathaysian geosynclines and geanticlines on the one hand, and their being interfered with, on the other, by the shear-forms to be dealt with later, that we begin to realize how independent a rôle they play in determining the coarser grain of the continental structure.

Mention has been made of the importance of the east and west mountain ranges in connection with the physiographical sub-divisions of modern China. Those east-west mountain ranges coincide with the east-west tectonic zones. The morphological connexion with the tectonics is, in this case, as real as it is apparent. One of these zones is located in the Tannu and Kentai Mountains, forming the northern border of the Mongolian block. The middle part of this zone is obviously disturbed by the Khangai Mountains, which more or less follow the " Irkutsk Amphitheatre" in trend, and which are undoubtedly related to the latter. Because of this powerful disturbance thrusting in from the north, the east-west zone could not have maintained its rectilinear front. The Tannu is slightly bent to the southeast in its eastern part, and the Kentai appears to have been displaced a little distance to the south of the position where it is due to appear had it not been disturbed by the Khangai Mountains. East-west folds of a powerful nature again appear to the north of the Amur province between latitudes 52° and 53° N. On the average, however, we may say that this east-west zone is located between latitudes 49° and 50° N. Geological information about these ranges is still too scanty to merit a detailed discussion.

The Inshan zone running between latitudes 41° and 42° N. divides the Mongolian block from the North China block; the Tsinling zone separates the North China block from the Middle China block, and is located between latitudes 33° and 34° N.; and the Nanling zone, much disturbed as it is, assumes an average latitudinal position in 25°-26° N., and forms the natural divide between the Middle China block and the South China block. These will be treated in the sequel.

The Inshan Zone

The Inshan zone may be conveniently dealt with in three parts along its length. The eastern part runs from the Kalgan area eastward across the Neocathaysian geanticline and geosyncline, disappearing for a time in the South-Eastern Highlands of Manchuria, and apparently strikes at a point on the continental border where the Kurile and the Honshiu arcs of the festoon islands of Japan join each other. In this part of the zone the morphological aspect is far more prominent than the tectonic elements, which are largely controlled by the Cathaysian directrices. The east-west morphological axis along this zone is not, however, entirely due to denudation. It has resulted, at least in recent geological times, from a broad folding or warping across the Cathaysian axes. And the discontinuity of the Cathaysian directrices in crossing this zone discloses the presence of a potential, if not

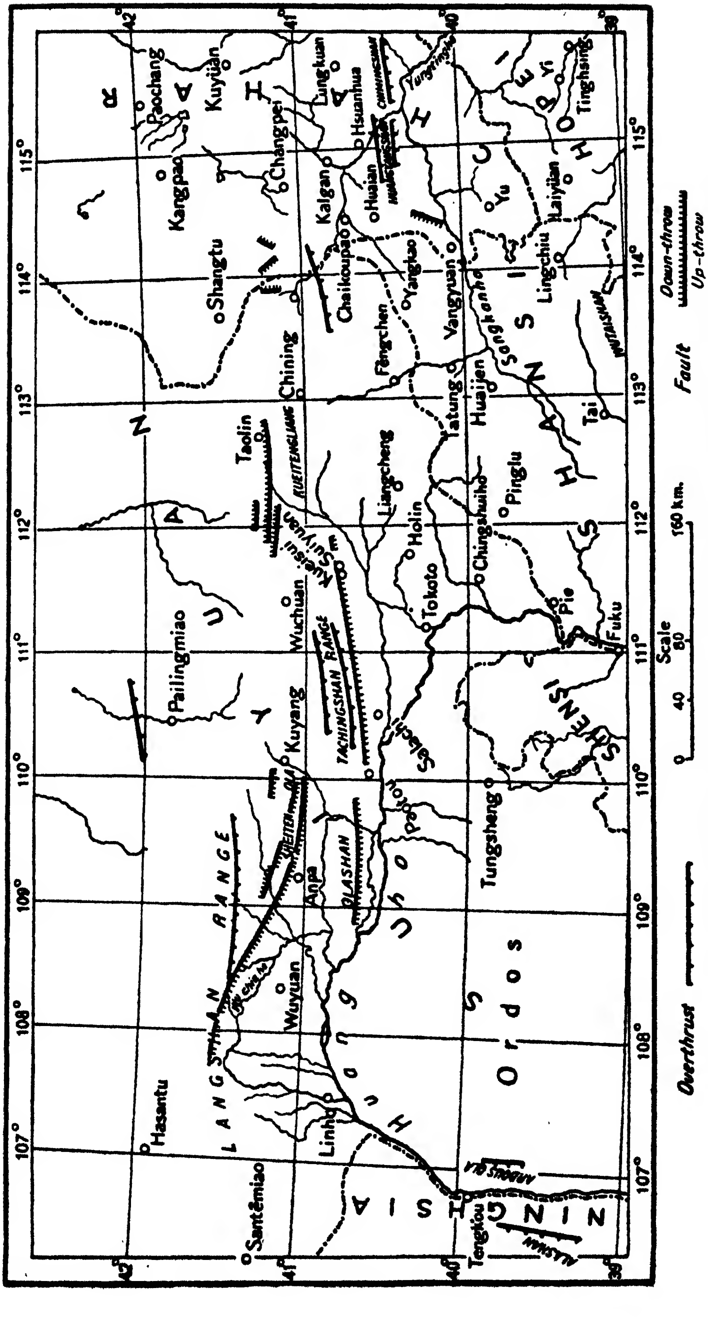

FIG. 67. Tectonic map of the Inshan Range showing thrusts and faults. (After C. C. SUN.)

explicit, tectonic cause which, by reason of its remarkable coincidence with a powerful east-west zone developed farther inland, cannot be attributed to anything but the same origin.

In spite of powerful Cathaysian folding, traces of an abnormal disturbance can be inferred or actually observed from place to place all along this east-west zone. The Kurile arc and Sakhalin folds suddenly terminate at the southern part of the island of Hokkaido, where the two groups of tectonic lines join and give rise to a great display of vulcanicity. Cretaceous strata are involved in the disturbance. It is difficult to appreciate the real significance of this tectonic discontinuity until we come to the mainland where the Cathaysian axes are again disturbed by east-west folds in the same latitudinal position. In South Manchuria we see that the thickest part of the sediments from the Sinian upward is developed along an ancient trough of east-west trend, with its axis running through the neighbourhood of Mukden. It formed an embayment, as it were, to the Cathaysian geosyncline. After the later Mesozoic movement, the east-west axis gave way to the Cathaysian directrices which obliquely run across the ancient trough. Complete suppression of the east-west axis was, however, not accomplished; for in the Tiehling and Fushun districts, north of Mukden, the axes of strong folding still run east and west. North-eastward, the east-west axis, the Cathaysian directrix and north-easterly faults combine to shape out the complicated structure of the Sihan coalfield. These structural lines affect the Jurassic and Cretaceous strata; and the disturbance intensifies towards the northern part of the coalfield. High dips to the north or south are frequently observed. In the Hsiaoshih coalfield in the Penchi district, south of Mukden, the Palæozoic coal-bearing series forms a basin elongated in the east-west direction, and is surrounded on the north and south by Cambrian and Ordovician limestones which dip into the basin at an angle varying from 30° to 70°.

On the western side of the geosyncline, which is filled up by sediments in the Liaoho Valley, at least three mighty overthrusts were observed by W. H. Wong in the Peipiao district, approximately in the same latitude as Mukden. These thrusts, according to the same author, come upon one another in succession generally from the north, but locally from the north-west. They occur in the central zone of the Great Khingan; and yet they differ notably from the general directrix of that range. It appears as if the structural lines coming from the north-east are here suddenly barred by a resisting mass of east-west trend. On their approach to this strange structural element, they are forced to adopt a west-south-west or even east-west strike. Such a forced adaptation on the part of the Khingan or Cathaysian directrices to the east-west lines is only partially successful in this part of the zone, but is nevertheless generally observable. In southern Jehol the general trend of the mountain ranges is no longer parallel to the true Khingan trend, but is bent to the west. The strike of the pre-Sinian rocks, which form a mountain range to the north-west of Kalgan, is, for instance, distinctly west-south-west. On the southern side of the mountains forming the borderland between Jehol and northern Hopei, nearly all the anticlines pitch to the south-west, *e.g.*, the Malanyu anticline which is the largest of the series. These mountains present a nearly rectilinear east-west front and dive abruptly under the North China Plain on the south. A broad folding across the Cathaysian axes has evidently taken place in the east-west direction in post-Mesozoic times, if it had not begun in the Jurassic or Cretaceous periods.

Clear evidence for folding along lines running east by north is offered by the Kalgan and Hsuanhua districts—an area of critical nature because of its situation on the southern border of the Mongolian Plateau and at the western end of the eastern part of the Inshan zone. More than that, three sets of structural directrices become confluent here. The subdued east-west axes to the east of this area now grow prominent; the modified Khingan directrices ultimately merge into the east-west folds to the north of Kalgan; and the combined Luliang-Taihang folds, which represent the Khingan in the North China block, begin to appear in the Hsuanhua district and to the south-east of it. Vigorous igneous activity in late Mesozoic and mid-Tertiary times in this transitional area probably have served to relieve a part of the intense and complex tectonic stress. Nevertheless, folding and thrusting are largely controlled by the east-west directrices.

On the southern border of the Kalgan Basin, highly inclined strata of the Sinian system unconformably overlie the gneisses and the schists with large intrusions of gneissoid granite. The Sinian generally strikes east-west, but the foliation of the gneiss varies from place to place. The Sinian is unconformably overlain by porphyries and acid lava with minor intrusions. This is the Kalgan Formation of G. B. Barbour, who regards it as either late Jurassic or early Cretaceous in age. In turn, the Kalgan Formation is unconformably overlain by the Nantienmen Series probably of Upper Cretaceous age. Both of these are folded with axes running east by north. But the younger formation is almost restricted to the Kalgan Basin in distribution, and is disturbed to a lesser extent. Then comes the extensive basalt flow which still forms a cap on the border of the Mongolian Plateau. Like the basalt flows on the eastern border of the Mongolian Plateau, it arrived in mid-Tertiary times.

South of the Kalgan Basin tectonic disturbance becomes even more manifest. The Sinian limestones and quartzite, together with the overlying coal-bearing series and tuff-conglomerate, form a series of anticlines and synclines in the Hsuanhua district with axes running nearly east-west. Farther south thrusts appear. The Sinian and Cambro-Ordovician limestones are thrust from the south or south by east upon the Jurassic coal-bearing series. One of the thrusts, namely, the Papaoshan-Chimingshan thrust, extends probably continuously for a distance of more than 25 km. The overthrust mass forms a series of prominent mountains arranged in a line which runs sometimes east by north and sometimes strictly east-west. In places, *e.g.*, at Huangyangshan, the uplifted mass probably became split by tear-faults. Still further south, the sharp east-west directrices begin to be replaced by broader folds gradually assuming the north-east trend.

From the Kalgan area westward to the west end of the Langshan, or Uniusu, appears a series of mountains which, in eastern Suiyuan, generally run west by south, such as the Kueitengliang and the Liangchengshan, but to the west of the capital of the Suiyuan Province they turn due west, forming three parallel ranges. The southernmost is the Tachingshan, the middle, the Ulashan, and the northern, the Sheitenula. The last-named is succeeded, on its north-western side, by the Langshan, which again proceeds due west on the northern side of the Huangho until it comes to its western extremity, where it apparently turns to the south-west and tends to join the Ulashan further south. But the east-west tectonic axes are, in fact, continued much further to the west. These mountains constitute the Inshan zone.

In this part of the Inshan zone the orographic axes almost entirely coincide with the tectonic. They are both as simple as they are striking. Being freed from the Cathaysian directrices the east-west tectonic trend is developed uninterruptedly. Owing, however, to the scanty stratigraphical record in the zone itself, it is almost impossible to ascertain the effect of the earlier movements upon this zone. Nevertheless, from the distribution of the Sinian limestone, C. C. Sun is able to restore a pre-Sinian intermontane basin stretching in the Suiyuan and Chahar area from the west to the east. The probable existence of land-masses or even mountain ranges both on the northern and southern sides of this trough is graphically described by the same observer. It may be added that this Sinian trough extended for a considerable distance both to the east and the west. To the east it must have run across the Hsuanhua-Nankou district, north-west of Peiping, and joined the Palæocathaysian geosyncline, as the Mukden trough did. To the west it extends even farther. We shall return to this feature when we come to deal with the western part of the Inshan zone.

Archæan gneiss and schist, Sinian limestone and quartzite, coal-bearing Jurassic sandstones, shales and conglomerates, and a late Cretaceous or early Tertiary conglomerate are the only formations which are involved in the eastern part of the Inshan Range. Unconformable relation between the Archæan and the Sinian, and between the Jurassic and the late Cretaceous or early Tertiary conglomerate, is flagrant. The discordance between the Sinian and the Lower Jurassic is less pronounced. The Lower Jurassic is believed to be separated from the upper part of the same system by a break.

An important thrust extends from the western part of the Kalgan area (Niuchinyingtze) to the north-east of Fungchenhsien (Santaokou) for about 70 km. along a continuous front which runs west by south. Garnetiferous schist and sometimes graphite-schist and gneiss of the Archæan are thereby brought from the south upon the Upper Jurassic sandstones and shales, which themselves are rendered into a concertina of isoclinal folds.

In the Kueitengliang Range, south of Taolin, the Jurassic completely disappears. The whole range is composed of the Sangkan Gneiss intimately folded with bedded marble. The axes of the folds run nearly east-west. Southward, bedded basalt similar to that occurring in the vicinity of Kalgan occupies a large area in the Chining district.

Towards the western part of the Inshan Range the stratigraphical development is a little more complete, though large gaps still exist. Between the Sinian and the Jurassic there is a series of conglomerate, sandstone and shale, with coal seams, to represent the Permian, sometimes resting directly but unconformably upon the Wutai formation or the Archæan, and another series of red shale and sandstone capped, in places, by a massive conglomerate supposed to be of Permo-Triassic or Triassic age. The Permian series occurs in the eastern and western parts of the Tachingshan, forming narrow bands either along the border of the Jurassic or involved in the thrusts of the Wutai rocks. But no notable discordance is observed between the Permian and the Sinian when the latter occurs directly below the Permian strata. On the southern side of the Langshan, a little distance to the north of Shihnakan, this coal-bearing series is strongly metamorphosed, being altered into dark grey phyllite, grey schist and coarse-grained quartzite with layers of graphite. All these occurrences suggest that the coal-bearing strata were originally deposited in basins elongated in the east-west direction. Although it is difficult to judge whether those basins were simply erosional features or resulted from renewed tectonic movements since Sinian times, the presence in them of massive conglomerates, together with the fact that their sites do not always conform with the Sinian basin, seems to point to the probability that folding of a mild nature along the east-west axes had occurred prior to the deposition of the coarse detritus.

The Permo-Triassic or Triassic series occurs in the Tachingshan and Sheitenula in some five districts. Generally it rests conformably upon the Permian coal-bearing series, but occasionally directly overlies the Archæan. This series was evidently deposited in the same basin or basins in which the Permian coal-bearing series was formed; but the massive conglomerates with large blocks of gneiss in the upper part of this series suggest a renewed growth of the surrounding mountains toward the latter part of the Triassic period. The most intense phase of the orogenic movement undoubtedly took place in post-Jurassic times. Overfolding and overthrusting involve the Jurassic strata and characterize the whole range of the Inshan, which displays crushing pressure between the Mongolian block on the north and the North China block on the south.

Two large thrusts are observed in the Tachingshan, each with an east-west strike, and both are parallel to the range. The northern thrust, named by C. C. Wang the Yinshan thrust, starts from the north of the railway station of Pingchouhai, and extends continuously for about 100 km. to Atakou, north-east of Paotuh. Wang has observed at several localities along the thrust plane that the Jurassic beds are pushed beyond the northern border of the Jurassic basin which forms the axial zone of that part of the range, and rest structurally upon the Wutai. On the other hand, the present writer recollects a case in the westernmost part of the thrust where the Wutai rocks appeared to override the Jurassic on the south with the development of a crushed basal zone. The thrust plane is as a whole rather steep, and may therefore be regarded as a "ramp."

The Yinshan thrust is succeeded on the south by the Paishihtoukou thrust bringing the Wutai rocks from the south upon the Permo-Triassic strata, which form overturned folds and even *scharniers* with their heads pointing to the north. Probably it extends for about 50 km., and is apparently cut off by the Yinshan thrust at Laotaokou, to the north of the Chasuchi station. More thrusts are developed farther south. They all assume the same general strike with overthrust to the north. There is hardly any question that all these thrusts were accomplished before the end of the Cretaceous. This vigorous movement was accompanied by scattered intrusions of granite, which is compared by C. C. Sun with the Lingsi Granite observed by Teilhard in the Khingan Range.

The Ulashan is composed of vertical beds of acid and basic gneisses. With the acid gneiss are interstratified banded marbles. They form a concertina-structure striking persistently east-west. Among them occurs a large body of gneissoid granite, obviously a pre-Sinian or even pre-Wutai intrusion, also elongated in the east-west direction. Narrow strips of intrusive diorite are found in the eastern part of the range. They, too, run east-west.

Basic gneiss, often impregnated with granite, plays an important part in the Sheitenula. As in the Ulashan, these rocks exhibit an east-west foliation which often runs through them vertically. Among them occur squeezed basins retaining altered Sinian, Permian, Permo-Triassic and Jurassic strata. These beds are largely found in the south-western part of the range. In its north-western part a broad exposure of Sinian limestone, fringed by the Permian coal-bearing series, dips at high angles to the south. In the neighbourhood of Shihnakan, the tectonic relation between these beds and the Archæan of the south is still ill-understood. According to C. C. Sun, there occurs an overthrust to the north, but judged from the section given by Teilhard, the Sinian appears to have been overturned and overthrust to the south. Farther east in the range, long and comparatively narrow strips of gneissoid granite, together with a few compressed outliers of Jurassic strata, serve to disclose the east-west axis of the mountain.

In the Langshan, the westernmost member of the Inshan Range in the strict sense, Archæan gneisses are folded together with Palæozoic strata. The folds are rather complex, but they all generally assume an east-west trend. On the southern side of the range the Archæan is apparently thrust to the north upon the Permian coal-bearing series. C. C. Sun assumes that this thrust is connected with the one which appears on the northern side of the Sheitenula already referred to. If this is true, it would extend continuously from the west to the east for a distance of no less than 120 km.

Numerous faults of the normal type also occur in this middle part of the Inshan zone. Sometimes they cut off the thrusts. As a rule, however, they run parallel to the strike of the folded strata. The largest of these strike faults are those which run along the southern side of the Ulashan and Tachingshan, throwing down the North China block against the Inshan zone. Similar faults are found on the northern side of the zone. They are particularly conspicuous to the south of Taolin and north-east of Wuchuan. Again they run east-west throwing successively the Mongolian block down against the Inshan. Oligocene basalt is in places affected by these faults. On the other hand, the red clay of late Miocene or early Pliocene age remains unaffected. Faulting must have therefore taken place in Miocene times.

The western part of the Inshan fold-zone is not usually recognized as such, partly because the mountain, or rather hill, ranges in this part of the zone are not so conspicuous as the Inshan proper, and partly because the Langshan with its tectonic axes tends to bend to the south-west, suggesting that it is connected to the Alashan further south. Such a branching connection of the tectonic axes may be real; but it does not vitiate the evidence for its continued existence towards the west, if, in that direction, the grain of the country is of east-west trend. Thanks to the valuable observations made by Teilhard de Chardin along a route from the western end of the Langshan to Etsin Gol, we are now in possession of some crucial facts which fully justify the conception of the continued existence of the Inshan zone across the desert from the east to the west.

In discussing the early history of the middle part of the Inshan Range we have referred to an east-west trough in which was deposited the Sinian limestone. This trough practically ran through the whole length of the middle part of the zone. Now, to the west of the Langshan, Teilhard observed an outstanding ridge composed of Archæan and intrusive rocks, associated here and there with silicified Sinian limestone, which, the same observer asserts, possibly forms a continuous " basement " of the ridge. The ridge is located in the latitude of about 42° N., that is, in about the same latitudinal position as the Inshan, and extends persistently between the western end of the Langshan and Etsin Gol for a distance of 250 km. According to a typical cross-section given by Teilhard at a point 110 km. east of Etsin Gol, the marmorized Sinian limestone, together with its overlying thin beds of Permian limestone, coarse sandstone and black slates of the Khangai Series (of Teilhard, but not Berkey), is folded to form an anticline overturned to the south. It will not be surprising if it be ultimately proved that the Sinian beds continue to extend along the same zone still further west until they join the Sinian formation in the Kuruktagh. If this is true, an east-west trough was already in existence in Sinian times, and covered more than 30° of longitude in the neighbourhood of latitude 42° N.

Formations of Wutai, Sinian, Permian, Permo-Triassic, Jurassic, Cretaceous, Pliocene and Pleistocene ages are developed in this part of the Inshan zone. Apart from the usual unconformity between the Wutai and the Sinian, evidence for a probable Hercynian movement is discussed by Teilhard. More pronounced, however, is the discordance between the Permo-Trias and the Jurassic. The unconformity between the Jurassic-Cretaceous sequence and the Pontian beds is equally flagrant. And lastly, the Sanmen Series of Upper Pliocene age is also folded. The last and important phase of orogeny along this zone seems to have occurred towards the end of the Cretaceous period. This agrees with the Inshan folding and thrusting not only in date, but also in trend; for the dominant strike of the rocks involved is likewise east-west with but minor variations of a local nature.

Granitic and porphyritic intrusions are abundant; and most of them appear to have arrived in late Mesozoic times. In the Uniusu district, west of the Langshan, a large body of biotite-granite, locally rich in tourmaline, is cut by numerous dykes and veins of garnetiferous pegmatite also rich in tourmaline. Some 20 km. west of Uniusu the disturbance is so intense and complicated that it almost defies description. Such an extraordinary disturbance may be regarded, as it is by Teilhard, as "*pointe de rebroussement,*" on the assumption that the main range of the Inshan turns at this point to the south. On the other hand, it is equally feasible to suppose that here lies the junction of the east-west zone of the Inshan and the north-south zone of the Alashan and its southern prolongation. The one interpretation is probably as plausible as the other. But by unduly stressing one side of the truth we are liable to overlook the other.

The Tsinling Zone

The Tsinling is one of the most obstinate east-west tectonic zones developed in eastern Asia. It plays not only an important part in determining the structural framework of central China, but it also constitutes a real factor in shaping out the configuration and tectonic pattern of the middle part of the Japanese Islands. For convenience of tectonic treatment this fold-zone may be divided into two parts along its length. The eastern end of the Funiushan in central Honan and the Nanyang-Hsiangyang Gap, of which mention has been made (p. 15), afford a natural line of division. It will be noticed that this line of division coincides with the western border of the inner Neocathaysian geosyncline—an important fact to be borne in mind. West of this line the Tsinling runs almost strictly east-west, and forms a continuous barrier-range between northern and southern China; but east of this line the range, with its structural axes, though still imposing as a natural divide, suffers much deflection. At the same time, it gradually subsides towards the east, being reduced to low hill-ranges on the southern side of the Huai Flood Plain, and eventually sinks under the Yellow Sea or Tunghai. But ultimately it appears in northern

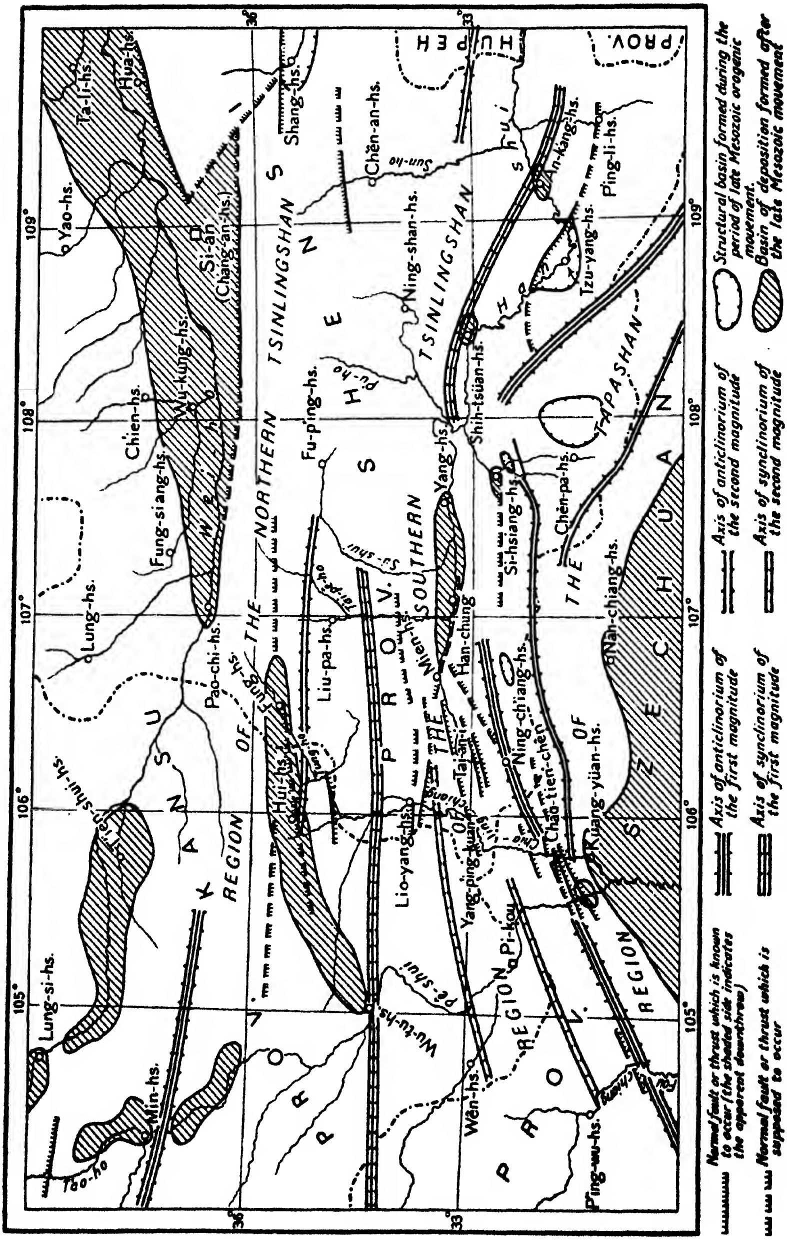

Fig. 68. Tectonic map of the western Tsinling and Tapashan. (After T. K. Huang.)

Kyushiu and the island of Shikoku in Japan, displaying undaunted tectonic vigour.

Continuing from the Kuenlun, on the northern border of the Tibetan massif, the main range of the Tsinling enters China proper along the southern border of Tsinghai and Kansu Provinces. Because of the existence of the Nanshan Ranges on the north and the Sikang Ranges on the south, the axis of this part of the mountain has not been clearly determined and differentiated from its associated ranges of different origin. But in the south-eastern part of Kansu, southern Shensi, central Honan and north-western Hupeh, the orographic axis of the range is as clear as the tectonic. It is especially well defined in southern Shensi, for here the Shensi Basin on the north and the Red Basin on the south offer a sharp contrast to the highly disturbed zone. Its position is almost precisely defined by latitude 33° N. on the south and 34° N. on the north.

Beginning with a clear-cut normal fault of enormous extent on the southern side of the Weiho, the range often suddenly appears with a wall-like front facing the north. This fault, or succession of faults, has evidently developed in relatively recent geological time, and throws the North China block down against the Tsinling. The whole range is composed of belts of metamorphosed formations all extending east-west.

The northernmost belt consists of a group of gneisses and schists extending at least over the mid-western part of the western Tsinling. The gneisses are usually banded, coarse-grained, and granitoid in composition, but now and then are rich in hornblende. In places they appear to merge into a true granite, and contain lenticles of hornblende-schist. The schists are either micaceous or chloritic, and are frequently exposed, according to Huang, in alternating position with the granitoid gneiss on the one hand, and on the other are apparently intercalated with, and succeeded by, beds of quartzite to the south of Tayukou, south-east of Sian. They also contain marble. Huang regards both the gneisses and schists as a single system, the Tsinling System, in disagreement with the classification of Richthofen, who considered the granitoid gneisses as being the older and the schists as belonging to the Wutai. As a whole, the gneisses are better developed to the west of longitude 108° E., and the schists become more important towards the east.

This belt of pre-Sinian rocks undoubtedly continues for a considerable distance farther east. At the eastern end of the western Tsinling, they should have been found, if they follow the same latitudinal position, somewhere not far south of Lushihsien. As a matter of fact, a "confused mixture of gneissic and amphibolitic rocks" does occur in that area, striking east-west and invaded by granite. The metamorphosed masses contain, in places, limestone much less metamorphosed. For this and other reasons, Teilhard, Barbour and Bien are inclined to regard them as Palæozoic, including Sinian. The Archæan or Wutai zone of the mid-western Tsinling must therefore either have entirely disappeared towards the border of the inner Neocathaysian geosyncline, or else have been partially covered by later sediments. The probability, however, still remains that at least a part of the schists mapped by Teilhard and his colleagues between the south of Lushihsien and Shangchi corresponds to the pre-Sinian belt of the west.

The northern belt of gneisses and schists in the mid-western Tsinling is followed on the south by a belt of an alternating series of dark green slate and well-bedded quartzite, named by Willis and Blackwelder the Heishui Series, and by Chao and Huang the Tsoshui Series. The rocks generally strike east-west and often stand on end. Willis and Blackwelder consider them as Cambro-Ordovician. Huang, however, would not exclude the possibility that they belong partly to the Sinian. To the west, this belt tends to broaden out, and turns to the north of west; to the east a broad zone of dark green slate appears to the south of the Laochienling Pass, south of Lushihsien. Here, it succeeds the gneissic and amphibolitic belt on its northern side, with layers of conglomerate and marmorized limestone lying near the contact, and with dykes of granite running east-west. Towards the southern side of the same belt, metamorphism decreases, and the slate is conformably overlain by a massive limestone, probably over 1,000 m. thick. The lithological character of the slate seems to suggest its equivalence to the Tsoshui Series of Chao and Huang.

The third belt in the mid-western part of the western Tsinling is represented by Silurian and Devonian limestones. They occupy a relatively narrow zone, but persist in their distribution in the east-west direction. They were found, for instance, by Obrutchev in the neighbourhood of longitude 108° E., between Wutuhsien and Minhsien. The Silurian attains a thickness of some 700 m., and the Devonian about 500 m. The two, though lying in apparent conformity, are separated in places by a massive conglomerate. In this basal conglomerate of the Devonian occur pebbles of gneiss and granite clearly indicating an orogenic movement which rejuvenated the old east-west ranges, and which took place at a time comparable with the Caledonian. Similar conditions prevail in the eastern part of the western Tsinling, namely, to the south of Lushihsien. Here the dark green slate with limestone is overlain by a conglomerate which forms the base of a massive limestone. The two formations are believed to be Silurian and Devonian respectively.

As mapped by Chao and Huang, the fourth important belt in the mid-western Tsinling, counting from the north, is a series of somewhat metamorphosed sediments whose age is not yet definitely known. These are divided into two formations by Huang. By tracing their stratigraphical relation Huang is able to demonstrate the fact that they are separated, in places, by the Lower Carboniferous limestone. The lower formation, or the Ketaszu Slate, consists of a thick, monotonous sequence of a well-laminated, dark grey, or greenish-grey, slaty shale, repeatedly folded into closed anticlines and synclines with axes running east-west. It is underlain by the Devonian limestone, and probably therefore represents the transition from Devonian to Carboniferous. The upper formation, or the Chenan Series, consists of alternating strata of thin-bedded grey limestone and grey or black shale, again a formidable sequence. The lower part of this formation apparently merges into the Lower Carboniferous limestone. The overlying formation in contact with it is, as far as is known, of Mesozoic age. Coals of inferior quality are now and then found in the Chenan Series, and the limestone in it sometimes attains prominence. The argillaceous beds are often rendered into true schists, especially towards the southern part of the mid-western Tsinling.

Thanks to the presence of the Lower Carboniferous, or Lioyang Limestone, which always forms a narrow and well-defined zone in the mid-western Tsinling, the general structure of the range is revealed with remarkable lucidity. Much of our synthetic knowledge about the structure of this part of the range is due to the valuable observations and finds made by Chao and Huang. In his comparative study Huang has rendered a useful service in systematizing the earlier knowledge contributed by Loczy, Obrutchev, Richthofen, and Willis and Blackwelder. He has also pointed out certain errors made by these observers, not altogether avoidable in those early days.

The long and narrow strips of the Lower Carboniferous limestone, often forming prominent ridges, do not restrict themselves to a single belt. They repeatedly crop out in the southern part of the mid-western Tsinling. But their general distribution appears to be narrowed down to the east. Thus in Lower Carboniferous times there appears to have existed in the southern part of the mid-western Tsinling an east-west trough, which was bordered on the north by a mountain range or a stretch of upland composed of the Archæan and the Tsoshui formations, and became narrower and perhaps shallower towards the east. These east-west features cannot be any other than those which had already arisen after the Caledonian movement. The observed conformity between the Devonian limestone and the Ketaszu Series, and between the latter and the Lioyang Limestone, indicates no movement of any importance that might have taken place in post-Devonian and pre-Lower Carboniferous times.

The last and the southernmost belt of the main range of the mid-western Tsinling consists of a series of schists, phyllite, banded gneiss, and crystalline limestone, often rich in streaks and veins of white quartz; sometimes the gneiss is impregnated with numerous thin layers of granite. This belt is particularly broad, occupying almost half the width of the main range of the mid-western Tsinling. It was met with by different observers along different routes. On account of the intense metamorphism that the rocks have undergone, they were assigned by different observers to different ages ranging from Pre-Cambrian to Mesozoic. By establishing the fact that they always overlie the Lioyang Limestone of Carboniferous age, for instance, near the village of Nuerpei in the Peshui Valley, Huang has produced positive evidence that they are of post-Lower Carboniferous age. Further, by comparing their lithological character with the Triassic and Jurassic formations as developed in the southern foothills of the range, it is justly argued that none of the rocks can be of Mesozoic age. Huang therefore considers them as a single metamorphosed formation, and calls them the Peshui Series. As such, the whole series is relegated to the Upper Palæozoic.

In the easternmost part of the western Tsinling, a broad zone of various schists with banded amphibolite, beds of metamorphosed limestone, layers of injected granite, and veins of quartz is developed to the south of the belt of Silurian and Devonian limestones already referred to. Apart from a Tertiary basin, the whole region between the Wutaoho Valley and a point a little distance north of Shangchi is entirely occupied by these metamorphic rocks. The southern boundary of these rocks is located in the neighbourhood of Shangchi, where it marks the southern boundary of the main range of the Tsinling in this eastern section. Judging from the character of the rocks as briefly described by Teilhard and his colleagues, and their relative position of occurrence in the Tsinling zone, one can hardly resist the inference that they represent the very same southern belt of the mid-western part of the range. The occurrence in the mica-schist of a layer of pure graphite near Shangchi shows that the series originally contained coal, and therefore might be reasonably correlated with the Peshui Series of the west.

The composition and structure of the main range of the western Tsinling may be briefly summarized as follows. The whole range can be transversely divided into three zones. They all extend east-west with local variation of strike. The northern zone consists of belts of highly metamorphosed Archæan and Sinian or early Palæozoic formations. Granitoid gneisses are well developed in the western portion of this zone, but are replaced by schists towards the east. As a whole, this zone seems to narrow down eastward. The middle zone consists of but slightly metamorphosed Silurian, Devonian and Lower Carboniferous formations. The Lower Carboniferous zone narrows down and thins out towards the east; while the Silurian and Devonian persist throughout the length. The southern zone is again characterized by profound metamorphism, consisting largely of argillaceous and calcareous sediments of Upper Palæozoic age. This zone is the broadest of the three and also the most uniform.

Within these three zones the foliation and bedding planes of the different formations generally strike east-west, and dip at high angles if not vertically. Large bodies of intrusive granite are also usually elongated in the east-west direction. Their crowded occurrence is particularly noticeable between longitudes 106° E. and 109° E. The one occurring on the southern border of the northern metamorphic zone is the famous Tapeishan Granite. Its colossal size can only be matched by the Hanchung Granite which appears on the southern side of the southern metamorphic zone, and is located in the same longitudinal position as its northern equivalent. We shall find excellent reason to account for the presence of these large bodies of sial material in the places where they are when we come to deal with the Tainanlung tectonic system (p. 298). Under these structural conditions, it is almost self-evident that here in this range we are dealing with the roots of old mountains.

Taking the position where the large granite bodies attain their maximum development, namely, between longitudes 107° E. and 108° E., as a region of "scharung," we see that divergent folds stretch out from the northern side of the Tsinling both to the north-west and to the north-east, and from the southern side of the range to the south-west and south-east. These extra-Tsinling folds are sometimes mistaken for parts of the Tsinling structure. They have in fact nothing to do with the Tsinling. Their origin and their allied elements will be dealt with later.

Important modification of the east-west axis of the range only happens in the neighbourhood of longitude 111° E. It will be recalled that the Siluro-Devonian belt to the south of Lushihsien still strikes east-west; but the southern metamorphic zone which follows on to the south no longer strikes in that direction, but south-east. This forcible bending of the Tsinling axis to the south-east is observable all along the western margin of the inner Neocathaysian geosyncline. It is clearly revealed, for instance, in the Nanyang district by the marble and its associated strata. Even as far north as the Mihsien district in northern Honan the same influence of bending is felt by the Wutai and Cambrian formations. Similarly, the Funuishan which may still be regarded as the eastern continuation of the main Tsinling axis stretches to the south of east.

Having summarized the main structural features of the western Tsinling, we now come to deal with the question of orogenic epochs involved in the different formations. To the Caledonian movement reference has already been made. After pointing out the mistake which Richthofen made regarding the alleged unconformity between the Permian or Triassic limestone and the "Silurian" on the northern border of the Red Basin of Szechuan—this has since been taken as evidence for Hercynian folding in the Tsinling—Huang proceeds to describe a case of importance bearing on the same question. In the vicinity of Tsaoliangyi, about 106° 40′ E., 33° 55′ N., between Paochihsien and Funghsien, a moderately disturbed coal-bearing formation, with *Neuropteris* and other plant fossils, rests unconformably upon the metamorphic series belonging to the northern metamorphic zone. The metamorphic series is either of Sinian or of Lower Palæozoic age, while the coal-bearing rocks are correlated with the Shansi Series of northern China. Since elsewhere in the Tsinling Range no discordance has been found between any members of the Sinian-Carboniferous sequence, the movement which caused this unconformity is believed to have taken place immediately before the deposition of the coal-bearing series. This deduction would place the movement either in the latter part of the Carboniferous or the early part of the Permian. Thus we may say that at least the northern zone of the western Tsinling was involved in the Hercynian movement.

The mountain range as it stands to-day, however, was brought about at a much later date. The only evidence for later folding so far available in the main range is afforded by a patch of conglomerates and sandstones occurring in the Funghsien (about 106° 30′ E., 33° 52′ N.) in the western part of the northern zone. This Tungho Conglomerate, as it is called, unconformably overlies the Sinian and Carboniferous strata, and is itself unconformably overlain by a series of red conglomerate, sandstones and clays which are lithologically comparable with the Eocene deposits in northern China. Since the production of a thick conglomerate presupposes a renewed growth of the mountain, and since the Tungho Conglomerate is attributed to the Cretaceous, it is thought that an orogenic movement occurred at the end of the Jurassic or in the early part of the Cretaceous, depending on the exact age of the conglomerate.

In the southern foothills of the western part of the western Tsinling evidence for Mesozoic movements is widely available. There, while the Triassic shales and limestone usually concordantly follow the older formation, the Jurassic or Rhætic coal-bearing series rests on different horizons of the older formation. A few typical examples will suffice to show this relationship. At Suchiaho in the Kuangyuan district (about 105° 50′ E., 32° 30′ N.), on the north-western border of the Red Basin of Szechuan, the Rhætic or Liassic coal-bearing series follows the Kialing Limestone of Triassic age without any notable discordance. Further north-east, a mighty series of conglomerates and sandstones, with shales and coal seams and plants indicating Rhætic or Lower Jurassic age, is developed in the Mienhsien district (about

106° 40′ E., 33° 10′ N.). These strata are somewhat metamorphosed, and often stand nearly vertically in direct contact with the metamorphosed Palæozoic formation of the southern zone of the main range. Examples of this kind are numerous. It would thus seem certain that an important movement took place after the formation of the marine Trias and before the deposition of the Rhætic or Liassic continental strata.

A still more important movement broke out at the end of the Jurassic. As noted above, the Jurassic coal-bearing series is highly disturbed on the southern border of the southern metamorphic zone of the main range. On the northern border of the Red Basin of Szechuan, the Lower Cretaceous with a Wealden fauna generally begins with a coarse conglomerate containing rounded pebbles of limestones and quartzite derived from the older formations. Sometimes this coarse material follows the Jurassic with apparent conformity but with a distinct break; at other times it overlies the older formations with a flagrant unconformity. Highly instructive is the case of the Huachang district (about 105° 40′ E., 32° 25′ N.) in the lower Peshui Valley, where the Lower Cretaceous conglomerate not only unconformably overlies the older formations, but is itself also disturbed, dipping at an angle of 50°.

The last-mentioned fact shows that there occurred yet another movement either in Upper Cretaceous or post-Cretaceous times. In the north-western part of the Tapashan and on the southern border of the southern metamorphic zone of the main range, a Shihtsuan Sandstone is developed in the basin of Shihtsuanhsien, where it unconformably overlies the Rhætic or Liassic series and the metamorphosed Upper Palæozoic strata. On lithological grounds the Shihtsuan Sandstone is correlated with the Fanchuang Sandstone of Eocene age, developed on the southern side of the eastern part of the western Tsinling. Its relatively undisturbed state of occurrence in a position where folding prevails would seem to indicate that no sharp folding has taken place since its deposition. This would place the folding of the Cretaceous beds in pre-Eocene times, if the age-determination of the Shihtsuan Sandstone is correct.

The normal faults developed in the western Tsinling vary in date. Most of them, however, are post-Eocene, for they cut the Eocene deposit. On the other hand, many of them do not affect the Pontian red clay. A few, particularly the northern boundary fault, may have had a continued growth down to Quaternary times. This absence of folding during mid-Tertiary times should not be taken as evidence for the absence of Mid-Tertiary tectonic movements along the western Tsinling. The development of faults is clearly associated with the rising of mountain blocks. The fact would be more correctly interpreted if we regard the phenomenon as a sign of old age on the part of the tectonic mountain range. If lateral pressure be applied to a zone of rocks already closely folded, the further effect will be not renewed folding but a general squeezing up, so to speak, of the mountain block. This was what actually happened to the western Tsinling when the Alps and Himalaya still had their young, plastic sediments converted into tangled folds.

The eastern part of the Tsinling differs from its western part in that it becomes involved in another tectonic system, which will be dealt with in connection with our discussion on the shear-form. From longitude 112° E. eastward, the main axis of the range is shifted for a considerable distance to the south to form the Tapeishan between Honan and north-eastern Hupeh. We know that such a shifting is a fact and not an arbitrary interpretation for at least two important reasons. First, from Lushi to Nanyang, and in fact in all the mountainous districts in western Honan, we can trace step by step the effect of forcible bending of the east-west zones so that they gradually adopt a south-east trend as they proceed eastward. Specific features of this effect have been already mentioned in connection with the description of the eastern termination of the western Tsinling. Secondly, the same northern metamorphic zone consisting of gneisses and schists is found in the northern part of the Tapeishan; and this is followed on the south by the Sinian, Silurian and other Palæozoic formations in the same regular procession, though these rocks are less metamorphosed in the southern part of the Tapeishan. The amphibolite which occurs to the south of Lushi and north of Shangchi with occasional layers of characteristic graphite is also found on the southern flank of the Tapeishan.

From the Nanyang-Hsiangyang Gap eastward almost to the eastern coast, the whole east-west zone is bent to form an arc, called the Huaiyang arc, with its convex front facing south or, more precisely, west of south. It suffices at present to identify the Tsinling Range across this part of the country in such a deformed shape. The question remains as to how such an extraordinary deformation was brought about. We shall see in the next chapter the outstanding features of the Huaiyang arc and its related tectonic elements, and shall further see how inevitable will be our conclusion regarding the powerfulness of a horizontal shear which converted the otherwise east-west zone into a powerful arc.

On the other side of the Yellow Sea, folds of east-west trend begin to appear in the northern part of Kyushiu, but here they are partially suppressed by the strong Cathaysian directrices. Further east, the true Tsinling structure is developed with full force across the Sakawa Basin in the island of Shikoku. In fact, the whole of that island is dominated by structural lines running nearly east-west. Cretaceous beds are involved in overfolding and overthrusting to the north. The mutual interference between the east-west zone and the Cathaysian directrices is remarkably well expressed in the slight tilting of the east-west zone to the south-west on the one hand, and in the structural peculiarity of central Japan on the other. The main island of Japan, or Honshiu, is divided into two tectonic units, the north-eastern and the south-western, which are separated by the so-called "Alps of Japan"—a region characterized by exceptionally powerful disturbance. This "Fossa Magna," as it is usually styled, is placed in such a position that it is hardly possible to refute its close relation with the east-west zone. As the Fossa Magna forces its way across central Japan from the north to the south, it suddenly terminates against the east-west zone at the Pacific sea-board. The junction of the two zones is the famous centre from which catastrophic

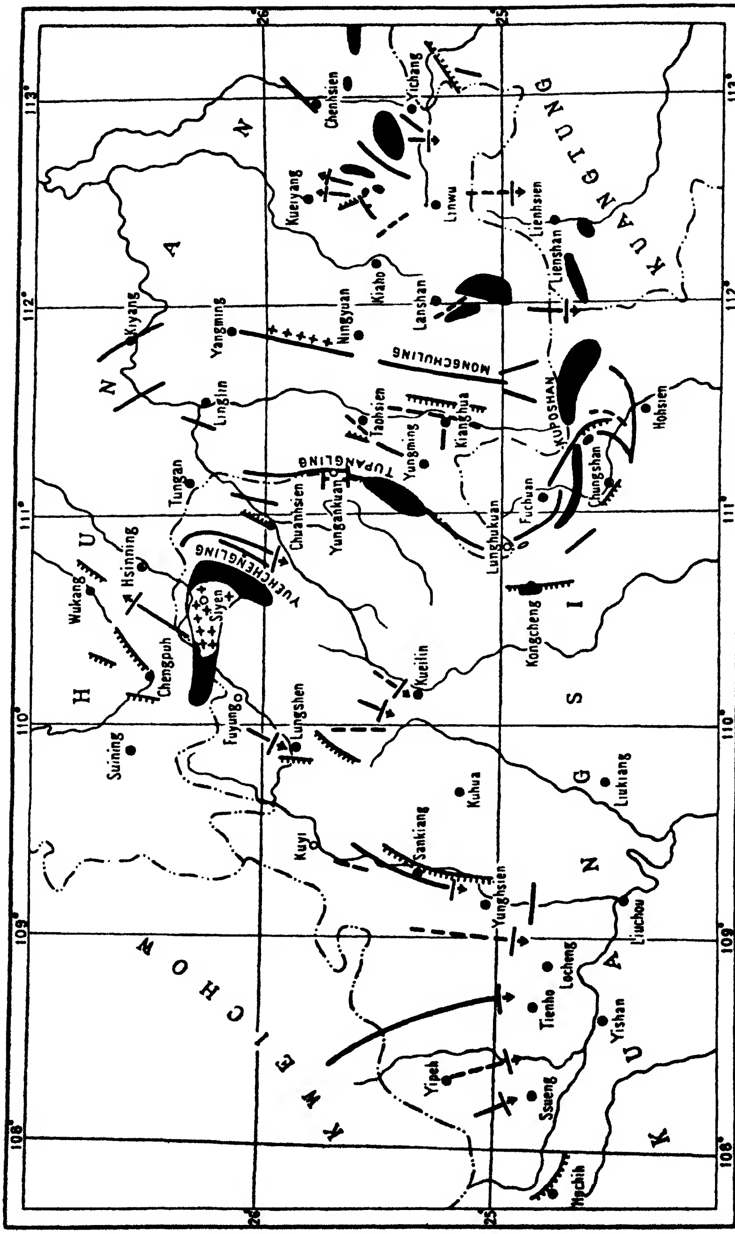

FIG. 69. Dominant structural directrices and granitic bodies in the middle part of the Nanling. Based on the observations of Y. Y. LEE, C. LI, H. M. MENG, K. CHANG, S. CHU, and the author.

earthquake waves are often sent out. The whole of the Honshiu geanticline seems to have bent against the east-west zone; hence the arcuate form. If this argument appears to be forced or the circumstances accidental, one needs only to recall the distant but potent influence of the Inshan zone upon the termination of the Kurile arc and the tectonic peculiarity of the island of Hokkaido.

The Nanling Zone

The Nanling Range differs widely from the Inshan and the Tsinling inasmuch as it had a more complex history and has suffered much deflection. Consequently its broader east-west trend has not always been clearly recognized by those who would only attend to the local structures. The structural complication arises from the fact that practically the entire zone is involved in the Cathaysian geosynclines and geanticlines. If we follow the trend of the Khingan-Taihang-Eastern-Kweichow geanticlinal axis southward, it will be seen at once that this line of structural importance cuts into the central Nanling on the northern border of Kuangsi. The region to the east of this line belongs to the inner Neocathaysian geosyncline. Farther east rises the geanticline of the South-Eastern Uplands. The western part of the range is involved in the "Yunnan arc," of which mention will be made later. Bearing in mind the fact that both the Inshan and the Tsinling have failed to maintain their strictly east-west axes as they come into the Cathaysian region, it will be no surprise to see the same failure being repeated by this southernmost east-west zone of folding. Nevertheless, the potent east-west directrices make themselves felt in the mountain structure as a whole, or actually

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EXPLANATION OF FIG. 69.

Full line: anticlinal axis.
Broken line: synclinal axis.
Short line with an arrow—short line suggesting the trend of cross-folding, and arrow the pitch of pre-existing folds.
Line shaded on one side: thrust with the overthrust side shaded.
Line with a stroke: fault with a stroke on the down-thrown side.
Black: granites.
Crosses: reported occurrence of granite.
Chain line: Provincial boundary.

crop out in certain parts of the range wherever and whenever chances afford.

That the western part of the Nanling Range has been dragged into the Yunnan arc is plainly demonstrated by the trend of the mountains which form the border between Kweichow and north-western Kuangsi. They steadily turn to the south-west as they merge into the eastern wing of the arc which gradually sweeps round to form the high mountains of north-western Yunnan. In this region where the dominant structural axes run west of north Gregory observed a striking example of east-west mountain folds near Hoking (about 100° 10′ E., 26° 30′ N.). In defiance of the general grain of the country, the beds are violently flung on end with east-west strike. Nothing would seem more fitting in explaining such extraordinary circumstances than to regard the feature as a repressed expression of the "recessive" east-west zone. Similar disconcerting features are expected to occur elsewhere in the same latitude across the Yunnan arc. Unfortunately our attention has not been directed along that line.

Further structural complication is introduced to the mid-western part of the Nanling by the development of the Kuangsi tectonic system. As will be fully discussed in the next chapter, this shear-form has impressed a north-westerly strike upon the Nantan district, north-western Kuangsi, and a nearly north-south strike upon the Sankiang district (about 109° 20′ E., 25° 25′ N.) and the main range of the Nanling to the north of it. But between longitudes 107° and 111° E., and in the neighbourhood of latitude 26° N., the structural relation between different tectonic elements can be easily understood by tracing the different stages of folding.

The oldest formation exposed in this part of the range is the Nanling Series, consisting of greenish-grey talcose phyllites, slates, schistose sandstones and conglomerates, and often containing a network of quartz veins. The axial zone of the middle Nanling is almost entirely composed of these rocks, extending from the neighbourhood of Linyun (about 106° 30′ E., 24° 30′ N.) to the north of Chuanhsien (about 111° E., 26° N.). In the western part, it tends to run to the south of west, but in the eastern part its extension is almost strictly east-west. The so-called Pashilinanshan, a lofty range between the Chengpuh district on the north and the Lungshen district on the south, is wholly composed of these rocks. This axial zone is not, however, a continuous belt, but only occupies the exposed cores of the anticlines whose axes vary from north-north-west to north-north-east in trend, that is, nearly perpendicular to the range. The axes of these anticlines and their accompanying synclines are strongly tilted. Those on the northern side of the range pitch to the north, while those on the southern side pitch to the south. Along the axial part of the main range the anticline is cross-folded, with the axis of the cross-folding trending east-west. The beds involved also strike east-west. There appears in the very axial part of the east-west fold a large mass of porphyritic granite some 15 miles wide, 60-70 miles long, extending probably discontinuously from the east of Kiangtuszu to the eastern end of the middle Nanling, namely, to the neighbourhood of the Hsiang-kuei Gap. This intrusive body strictly follows the east-west axis. Even the huge phenocrysts of orthoclase in it are arranged in the east-west direction. Foliation developed in the granite also strikes east-west.

Unconformably overlying the Nanling Series is the Chingchih Formation, which begins with a massive conglomerate followed by black shale intercalated with impure limestones. The limestone members are rather dominant in the northern part of the mountain, but almost entirely disappear in the Lungshen district, in the southern part of it. The black shale is sometimes highly bituminous, and the conglomerate often contains beds of black flint. Here and there they are found in the axial zone of the main range. But more often they are distributed in the foothills on the north and the south. Lower members seem to thin out towards the west. The lithological character of the whole sequence strongly resembles that of the Ordovician beds of central and south-western Hunan. The presence of Silurian in the upper part of this series is, however, not excluded.

An unconformity of the first magnitude is observed between the Devonian and the older beds. The unconformable contact is particularly well exposed in the northern part of the range, becoming less clear towards the southern side. Such an unconformity is undoubtedly due to the Caledonian movement, which had also affected, as far as stratigraphical records permit us to judge, central Hunan and the Sikiang Valley. The general trend of the folds which then arose was essentially Cathaysian, but with local modification. In the middle part of the Nanling, the Devonian as a whole is represented by several series of sediments, which begin with coarse detritus and become more calcareous as the sequence is followed upward. The uppermost member is, however, restricted to the northern side of the range. These facts indicate that while the Palæocathaysian geosyncline continued its growth after the Caledonian movement, a gentle uplift of a land-mass along the east-west direction had begun in the middle part of the Nanling.

Lower Carboniferous shales, sandstones and limestones, locally with seams of impure coal, are developed both on the northern and southern sides of the main range of the middle Nanling. They overlap the Devonian formations, but no noticeable discordance has been observed between the two formations. Middle Carboniferous limestone is well developed both to the north and the south of the middle Nanling, but it is represented by a break in the main range, signifying a renewed uplift of the east-west land-mass which had been initiated at the end of the Devonian period. Uralian transgression again brought the greater part of the eroded Moscovian land under water which probably persisted to the end of Lower Permian times. Then occurred the main phase of the Hercynian movement, which, as far as the middle Nanling is concerned, was of such a nature as to form broad folds, but certainly cannot be compared with the Caledonian in intensity. In the northern part of the range, *e.g.*, in the Wukang district, the disturbance appears to have taken place immediately before the Neoschwagerina Stage. Along the southern border of the range, between Kweichow and Kuangsi, namely, in the Tunglan, Linyun, Fengshan, Hochih and Nantan districts, the Maping (Uralian) and Chihsia (Lower Permian) Limestones are often transgressive upon the Devonian; but the important stratigraphical discordance occurs between the Maokou Limestone with *Neoschwagerina* and a series, consisting of yellow sandstone and black shale, corresponding to the Loping coal-bearing series of Middle Permian age.

At all events, more than one phase of Hercynian movement is recorded in the middle Nanling. From the Devonian upward, the strata are generally folded into anticlines and synclines whose axes run north-north-west in the western part of the middle Nanling (Tunglan, Linyun, and Nantan districts), nearly north-south in the central part (between Yipeh and Yunghsien districts), and north-north-east in the eastern part of the range (Lungshen district). As soon as we come to the southern foot of the range all the folds pitch decisively to the south. At the same time they tend to broaden or to spread out so as to form synclines or anticlines with their axes running east-west. The farther south we go from the foot of the range, the more notable becomes the east-west trend of the axes. A similar type of structure is observed to the south of the city of Wukang in the northern part of the range.

At first sight these structural facts seem to demonstrate fairly conclusively the chronological relation between the two sets of folds. Those with their axes running across the range are apparently developed in an earlier stage, and therefore probably belong to the Caledonian and Hercynian, and those controlling the east-west extension of the present range ostensibly belong to a later generation. Careful examination of the interlocking relation between the two sets of features reveals, however, certain objections to such a simple conclusion. We have already seen that a rudimentary form of the middle Nanling came into existence in the middle of the Carboniferous, though it was largely planed down before the Uralian transgression. The Middle Permian coal-bearing series occurs both on the northern and southern sides of the range, but is absent from the main range itself. These facts point definitely to an uplift of the east-west land-mass during the Hercynian disturbances. On the other hand, the Devonian-Lower Permian strata are folded together in the foothills of the range with the axes running nearly north-south. They must therefore be dated as post-Lower Permian. In the middle part of the Nanling Range neither the Trias nor the Jurassic is present. But a little distance to the south-west of the range, *e.g.*, in the Pakseh district, the Triassic sandstone is conformably folded with the Palæozoic, which follows the same system of folding as the foothills of the Nanling.

From such entangling facts as these we can at least draw two safe conclusions. First, at least the eastern part of the middle Nanling was elevated along a line approximately coïnciding with the present range during the Hercynian movements. How these movements affected the minor structure of the range and its neighbourhood is another question. Secondly, the old structural features transverse to the present range were involved in movements which took place later than the Triassic period. Whether such movements are "posthumous" is another question. Nevertheless, it appears generally true that the Caledonian disturbance impressed the middle Nanling region essentially with the Cathaysian trend, and that the Hercynian disturbances partly accentuated the Cathaysian trend, partly modified it due to the development of other tectonic systems, and partly forced up the east-west mountain mass. The dominant east-west axis in the central zone of the main range, and the east-west folds on both sides of the range, are without doubt largely due to a movement or movements which occurred at a much later date.

For lack of sedimentary record, we cannot determine the later orogenic epochs in the middle Nanling. Evidence is fortunately available in the eastern part of the range. In the Kenkou coalfield of the Yichang district, southern Hunan (about 113° E., 25° 10′ N.), the Jurassic coal-bearing series rests upon the Lower Carboniferous and Lower Permian limestones with a flagrant unconformity, and is itself rather strongly disturbed, dipping at 40°-50° to the south and striking nearly east-west. North of the city of Yichang the red sandstone either of Upper Cretaceous or more probably of early Tertiary age again unconformably overlies the older beds. This red sandstone strikes due east-west and dips south at 15°-20°. Thus, at least three more orogenic movements occurred in the Nanling Range: one of these took place before the Jurassic, another was post-Jurassic or Upper Jurassic, and a third post-Cretaceous or mid-Tertiary. The last two, if not all three, gave rise to folding along east-west axes. The two movements separated by the deposition of the Jurassic coal-bearing series are evidently far more important than the one which occurred in post-Red Sandstone times. We may therefore conclude that important folding along east-west axes took place in the Nanling in late Mesozoic times. The dating generally agrees with what we have already found in the Inshan, Tsinling, and the Cathaysian region.

The eastern Nanling is, however, not an east-west range. It is arranged in an arcuate form like the eastern Tsinling in the morphological sense, but tectonically it is very different. Its special features will be dealt with in the next chapter. At present our purpose is to find out specific features to ensure its connection with the middle Nanling, and to justify our belief that it does form an integral part of the Nanling Range, however deflected and laterally disturbed. In the first place, we find old formations, similar or equivalent to the Nanling and Chingchih Series of the middle part of the range, widely exposed in the mountains to the south-east of the Hsiang-kuei Gap. In the Tupangling, for instance, the Chingchih Slate is unconformably overlain by Devonian sandstones and shales. Each of these formations is of the same lithological character as their equivalent in the middle Nanling. They appear in the axial part of the Tupangling anticline whose axis is almost due north-south, extending continuously for more than 120 km. To the south-east of this anticline the range turns to the east and then north of east, forming the border-range between Hunan on the north and Kuangsi and Kuangtung on the south. In this range gneisses and schists of Archæan or Wutai age are unconformably overlain by talcose shales intercalated with schistose sandstone resembling the lower part of the Nanling Series. Unconformably overlying this shale is a series of slates and sandstones comparable with certain facies of the Chingchih Formation of the middle Nanling. This is in turn unconformably overlain by the Devonian sandstone. The last-named unconformity undoubtedly represents the Caledonian movement so prevalent in the middle Nanling. These will suffice to show the extension of the Nanling Range into that arcuate group of mountains which succeed one another to the south-east of the Hsiang-kuei Gap, so far as the early sedimentary and dynamic history is concerned.

Still more significant is a series of intrusive granites arranged along the curved axis of the eastern Nanling. We have already seen that an elongate body of granite forms the axial zone of the eastern part of the middle Nanling. It disappears in the Hsiang-kuei Gap, but reappears in the Tupangling. Large masses of similar granite are found in the border-ranges between Hunan and Kuangtung, such as the Kuposhan, Lienshan, Hsianghualing and Kitienling masses, and between Kiangsi and Kuangtung. Between the two last-named provinces a granite body is reported to extend from Jenhua (about 113° 45′ E., 25° 20′ N.) eastward past Nanhiung for a distance of about 70 miles. There cannot be any better means than this string of granite bodies for demonstrating the continuous nature of the Nanling axis. In the western part of the eastern Nanling, while the granite masses as a whole follow an arcuate line of distribution, the individual bodies, together with the strata into which they are injected, often show an obstinate east-west trend. From longitude 113° E. eastward, the range with its granite axis resumes the normal east-west trend as far as southern Kiangsi, where the axis strikes against the southern part of the Neocathaysian geanticline of the South-Eastern Uplands. After describing a minor arc in its terminal part, the Nanling directrix apparently merges into the Cathaysian to the north-east.

The influence of the east-west axis persists, however, further to the east. Across the Formosa Channel and the northern corner of the island of Formosa we see that a row of islands forming the southern part of the Riukiu arc describe a sharp bend as they approach Formosa. Bathymetric maps show that the submerged continental border follows a similar bending. With the fact in view that the Kurile and Honshiu arcs are respectively determined on their southern ends by the Inshan and Tsinling zones, it does not appear to be an accidental coincidence that here, too, the Riukiu arc terminates in the latitude of the Nanling zone.

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CHAPTER VII

SHEAR-FORMS

No less important than the Cathaysian geosynclines and geanticlines and the east-west fold-zones are several types of geotectonic shear-forms in determining the major structural features of eastern Asia. From theoretical considerations, as well as from laboratory experiments with suitable material, it has been shown that this third group of tectonic types arose from horizontal shear of the continental masses involved. Consequently, they are simply called shear-forms without hesitation. Each type of shear-form is characterised by a specific pattern or combined setting of a group of folds, which may or may not be accompanied by thrusts, and of faults, which generally run across the axes of the folds.

A few standard types of such shear-forms have been established, based on field observations and experimental reproduction on a small scale. They are found to be particularly important in the region of eastern Asia because of their lucid development and their controlling influence over the structural framework of the different regions. Under normal circumstances it is quite easy to recognise them. But interference from other tectonic systems often brings in a source of confusion. Nevertheless, by tracing and identifying their component elements with those of the standard type, one can not only verify their existence, but can also often understand how and why the modification is brought about. Parts of a given shear-form may take advantage of the weakness of a tectonic zone which belongs to an entirely different system. The two tectonic systems would thus be partly placed in juxtaposition. Again, a new shear-form may be induced upon an old one of different type in the course of time. In this case, a good deal of confusion may arise. After a careful analysis, both with regard to time and space, of the individual tectonic elements, it is usually possible to separate the superimposed system from the one out of which it is developed. The important fact to be noted in this connection is that the characteristic features of the older system are never totally destroyed through the development of the younger. On the contrary, the renewed tectonic forces engaged to build up the new system are often found to be unable to raise the necessary folds to the normal refinement because of the presence of the old, if the two sets conflict in trend.

A.—THE ξ TYPE

The ξ type of shear-form comprises a group of parallel folds, spread over a large area, all more or less comparable

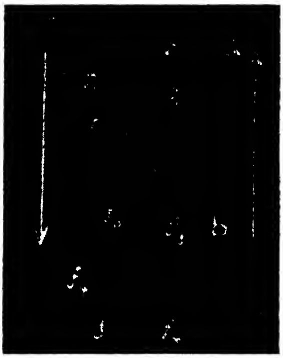

FIG. 70. Parallel folds (abd) of the ξ type with faults f_1-f_4 running across, produced on wet paper by a simple shear applied in the direction indicated by the arrows.

in magnitude and persistent in trend, which is usually north-east. The parallel folds are frequently, though not always, accompanied by faults running across the strike of the strata, depending on the mechanical properties of the rocks involved and the intensity of folding.

Ever since the time of R. Pumpelly the structure of Siberia, Mongolia and northern China is known to be dominantly controlled by numerous folds running north-east. This pioneer observer proposed to name them the "Sinian System of Folding." Von Richthofen used, however, the term Sinian in his stratigraphical classification. Its usage in stratigraphical literature has since been established. To avoid this unfortunate confusion, we might use the term

Cathaysian in lieu of Sinian in the tectonic sense, for the reason stated below.

In following the development of the Cathaysian geosynclines and geanticlines we have noted that, within the Cathaysian region, folding with a north-easterly trend repeatedly has taken place since Sinian times. The folds are all associated with the growth of the synclinoria and anticlinoria, but are interrupted at regular intervals by the east-west zones. As soon as the east-west zones of folding are left, the normal north-east trend is generally resumed. As far as the Cathaysian region is concerned, there are only a few exceptional areas in which the north-easterly trend is disturbed by the presence of other tectonic systems. These north-east directrices may therefore be conveniently referred to as the Cathaysian trend. It must, however, be understood that such a general term denotes neither a definite period of folding nor necessarily a single tectonic system.

From Transbaikalia down to South Manchuria, the grain of the country is dominantly controlled by the Cathaysian trend. We have already entered upon a somewhat detailed discussion on the subject in connection with the structural development of the Great Khingan and the region to the east of it. The sharp folds and violent thrusts found in this region undoubtedly resulted from late Mesozoic movements. But gentle flexures along the same north-easterly direction probably began to develop already in Sinian times, as may be inferred from the general trend of the Palæocathaysian geosyncline and Palæocathaysia. The same state of affairs exists in the north-eastern part of the Shansi geanticline and in the eastern part of the Shantung massif.

Another vast area swept by endless waves of folds of north-east trend is that of south-eastern China, comprising the provinces of Fukien, Chekiang, southern Anhui, Kiangsi, Kuangtung, and a large part of Hunan. It will be realized from our previous discussions that the whole of this area lies within the Cathaysian region. Owing to the absence of other tectonic systems, the Cathaysian directrix rules supreme. It controls not only the local structure, but also the regional tectonics as well. The eastern part of this

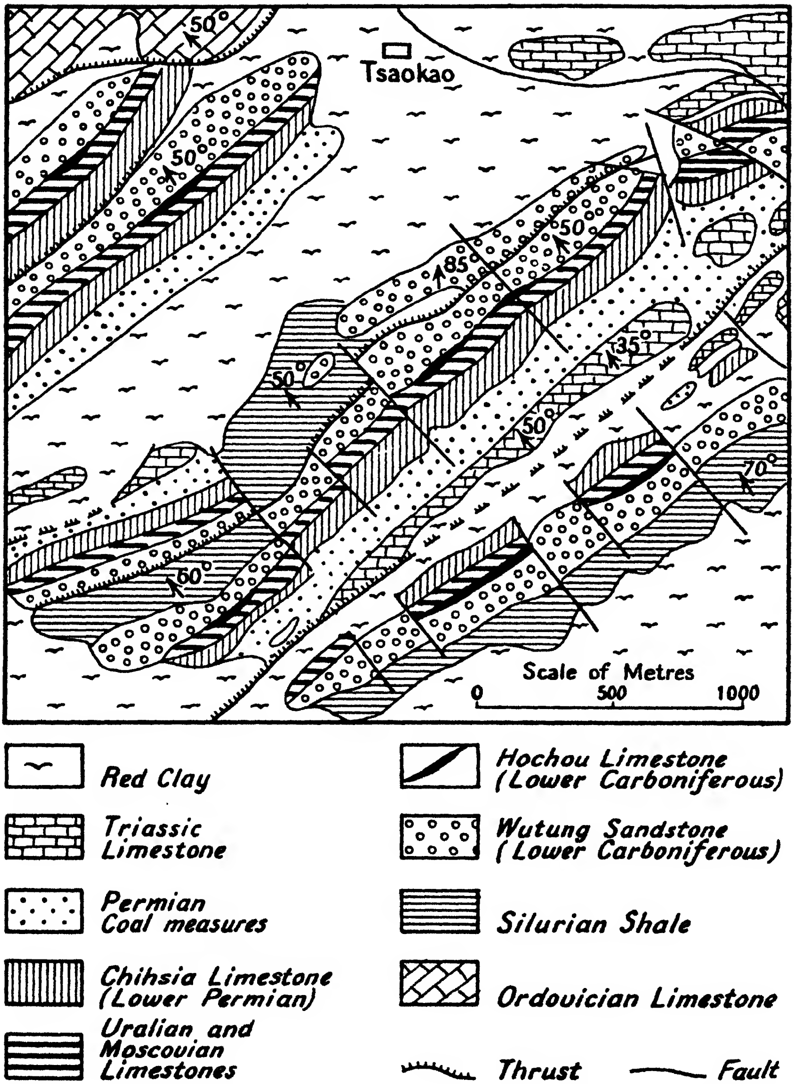

FIG. 71. Geological map of the Lientaishan area, north-western Hohsien, Anhui, showing the ξ type of structure. (After C. Y. LIU.)

region, namely Chekiang and Fukien, is, as a whole, elevated to form the Mincheh geanticline, of which mention has already been made. This gigantic anticlinorium also assumes the Cathaysian trend. In fact, it is a direct descendant of Palæocathaysia.

A rather sharp boundary exists between this uplifted region and the relatively low-lying, folded land on the north-west. Along the boundary runs an extensive range, also Cathaysian in trend, locally named the Sienhialing, the Wuyishan and the Shaling. The northern end of these ranges almost reaches the southern side of the Hangchow Bay as one branch, and the Tienmongshan as another. Towards the extreme south, the Shaling Range bends somewhat abruptly westward so as to join the Tayuling or the easternmost part of the Nanling. These ranges form the provincial boundary between southern Anhui and Kiangsi on the one hand, and Chekiang and Fukien on the other.

A relatively broad zone of Archæan gneisses and schists together with gneissoid granite is well developed in the central and southern parts of these ranges, but in the northernmost part the Archæan is generally buried under the Lower Palæozoics. South-east of this zone, that is, within the Mincheh geanticline, stratigraphical records are rather scanty. The Archæan is here and there overlain in the northern part of this region by a series of schists and phyllites supposed to be of Sinian age, but in southern Fukien these rocks are absent. There, the Archæan underlies a series of quartzite and slate, with beds of fireclay and carbonaceous sandstones and shales. They probably belong to the Carboniferous. These continental beds are unconformably overlain by the Lower Permian limestone and the Middle Permian coal-bearing series with the *Gigantopteris* flora. In the northern part of the geanticlinal region, formations similar and equivalent to these are also developed, but to a much less extent. These stratigraphical facts show that the region was involved in the Hercynian movements. Since no folding other than the Cathaysian type prevails in the area, it is practically certain that the Hercynian folds were generally of north-east trend and of broad nature.

Jurassic sandstones and shales, often coal-bearing, attain a wide development over the northern part of the geanticlinal area, and are separated by an unconformity from the underlying rocks. The most remarkable and widely observed unconformity over the whole region is that which comes between the Jurassic and the Cretaceous. The Cretaceous may rest directly on any formation older than itself, and is much less disturbed than the Jurassic. The lower part of the Cretaceous consists of red or purple tuffaceous sandstones, conglomerates and shales, and the upper part of a thick sequence of bedded rhyolite, often porphyritic and sometimes showing fluidal structure. Granite, granite-porphyry and quartz-porphyry are associated with these volcanic rocks. In southern Fukien, syenite and diorite bodies and lamprophyre dykes frequently occur among the intrusions. To the east of a line drawn from Kuhtien to Tehua the whole country down to the coast is almost entirely occupied by granite. Since the Cretaceous strata in the southern part of the region are generally supposed to be unaffected by them, their post-Jurassic and pre-Cretaceous age is assumed. In Chekiang, however, the Cretaceous beds are also invaded by igneous masses. This point requires further investigation.

It can hardly be doubted that the main phase of folding in the Mincheh geanticline occurred either in the latter part or at the end of Jurassic times. This does not, however, imply that the post-Cretaceous movements are of no importance. The Cretaceous beds are moderately folded along the same Cathaysian direction. They are unconformably overlain by red clay and conglomerate, believed to be of early Tertiary age. The final phase of igneous activity is represented by basaltic flows along parts of the coast. The precise period of eruption is, however, yet undetermined.

The axes of the anticlines and synclines developed in this region all run north-east, with local variation to north-north-east or east-north-east. They generally become broader towards the coast, but more compressed towards the western border of the geanticlinal area, that is, towards the Sienhialing and Shaling. This tendency of the folds to become more compressed towards the north-west culminates in thrusting in the Changhsin coalfield, north-western Chekiang, and is further indicated by high dips recorded all along the Shaling, north-western Fukien, and the steep north-western limbs of the synclines and anticlines in the Lungyen and Nanching districts, southern Fukien. In the last-named districts, the folds become obviously more crowded toward the north-west. In tracing the south-westerly or north-easterly extension of each linear series of folds, it is often found that the axis of a fold is not continued along the same line as that of the next succeeding one, but is laterally displaced to a greater or less extent. There must be numerous faults running across the folds, but so far they have not been mapped. Strike faults are frequent, breaking up the region into numerous strips in the form of *graben* or *horsts*. The Cretaceous beds often owe their preservation to large normal faults on the north-western and south-eastern sides of a *graben*. These strike faults are obviously younger than the folds, for an anticline is frequently found in a *graben*.

An extraordinary feature occurs in the southernmost part of the Mincheh geanticline. This is a thrust observed in the vicinity of Shihching, between the Nanching and Lungyen districts. The thrust-plane is inclined to the south-west at an angle of about 20°. Permian limestone is pushed to the north-east, and rests mechanically upon the Triassic shale. The Cathaysian directrices are modified to a considerable extent in the neighbourhood of Lungyen. This line of disturbance probably marks the junction between the Nanling zone and the Cathaysian folds. There then we have some evidence to show that these two groups of tectonic features do not form a harmonious whole by insensible gradation, but that they conflict at their junction, each displaying its independent character.

In the neighbourhood of the Wuyi-Shaling Range, Palæozoic formations, including the Ordovician, are closely folded in the Cathaysian trend. Further north-west, an endless series of Cathaysian folds is propagated towards the Yangtze Basin, involving the Palæozoic as well as the Mesozoic formations. Apart from local variations they all strike north-east. Granitic intrusions are still found in the region near to the boundary range, *e.g.*, in the Shehsien, Huangshan, and Kihmen districts; but they decrease in size and frequency towards the Great River. The Cretaceous formation, too, becomes often free from igneous material. While the folded strata are often faulted along their strike, there also occur numerous faults running across the strike. Such cross-faults generally trend north-west, namely, perpendicular to the strike of the folds. They have been duly noted by L. F. Yih and C. Li in the Hsuancheng and Chinhsien coalfields. A large cross-fault of this class is mapped by S. Chu in the western part of the Kueichih district (about 117° 20′ E., 30° 30′ N.). These cross-faults will undoubtedly prove to be characteristic over the whole region when detailed mapping is done.

Sometimes the Cathaysian folds become so compressed that they are turned over into thrusts. When the overthrust mass glides along an uneven floor, it may become split across its front and so develop a series of more or less parallel faults. Such splitting faults, as they may be called, generally die out within short distances from the front of the overthrust mass, and must therefore be distinguished from true cross-faults, which are brought about by more widely prevailing tensile stress associated with the shearing movement.

The Cathaysian folds are not restricted to the Lower Yangtze Valley, but extend into Kiangsi and north-eastern Hunan. In western Hunan they are, however, replaced by another group of folds having a north-north-east trend of the Neocathaysian type. These are undoubtedly related to the geanticline of the eastern Kweichow Plateau. They arrange themselves *en échelon* and extend as far south as eastern Kuangsi. The Shuehfengshan, Tientsenshan, Yunshan and Yaoshan are among the more outstanding elements of this modified Cathaysian or Neocathaysian system. Their post-Triassic and pre-Tertiary age is indicated by a great unconformity between the Trias and the Red Sandstone.

In south-western Anhui, Chu has also observed an unconformity between the Middle Permian coal-bearing series and the Lower Permian marine formation. The discordant relation between the beds in question is indisputable, but the strike of the formations below the plane of unconformity only differs slightly from that of the coal-bearing series. Similar cases are known elsewhere in the Lower Yangtze Valley, indicating that Cathaysian folding was already brought about in Hercynian times, but became more exaggerated after the late Mesozoic movements.

So far we have considered groups of parallel folds with Cathaysian trend occurring in the eastern part of China, and have noted that they are particularly well-developed in south-eastern China. Now we come to a region in the north-western part of the country, including western Mongolia, roughly defined on the north by the Khangai Mountains, and on the south by the Nanshan Ranges. In crossing this vast expanse of desert land from north to south, we find an important range lying across our way. This is the Mongolian Altai running south-east, brought about largely by Tertiary faulting. The altered sediments extending both to the north and the south of this mighty range are so folded that they do not, as a rule, follow the strike of this range. In the southern part of this area, between Hami and Suchow, the desert floor is reported to be entirely composed of dark slates, associated with a few limestones and invaded by numerous bodies of biotite-granite. The slates are often so strongly metamorphosed that locally they pass into mica-schists. Their general strike appears to be not incomparable with the Cathaysian. The age of the slates and limestones has not been satisfactorily determined. Their disagreement in structural directrix with the powerful Altaian trend would seem to suggest an age older than the Hercynian. All these parallel folds offer examples of the ξ type of shear-form.

It has been repeatedly demonstrated by experiment with thin sheets of material that a series of parallel folds is produced when they are subjected to a horizontal shear. The axes of the folds generally make an angle of about 45° with the direction in which the shear is applied. When the shearing movement is carried too far, then fractures more or less perpendicular to the axes of the folds result. Such fractures correspond to the cross-faults occurring in nature. Simple analysis of shearing stress proves conclusively how such a stress may be resolved into compression and tension at right angles to each other and at 45° to the shear. Applying this principle, we see then that the parallel folds are induced by the component compression, and the faults by the component tension, the two being due to a single process of shear.

B.—THE η TYPE

The η type of shear-form consists of a group of curved folds, which, in the anterior part (or that part of the system

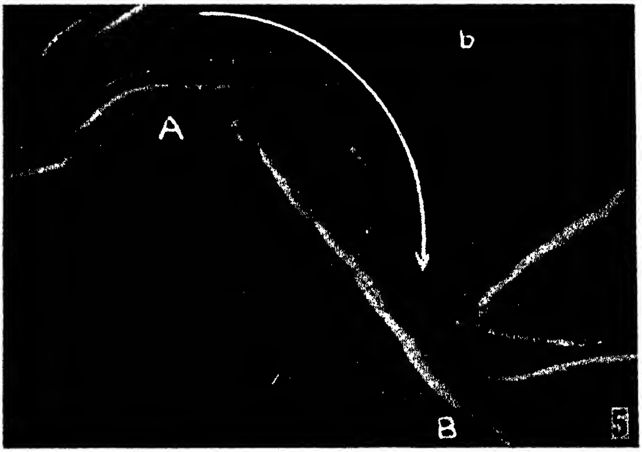

FIG. 72. Folds of the η type, produced on a sheet of wet paper by fixing the paper at A and B and applying a twisting movement as indicated by the arrow.

which surrounds the nuclear region), more or less concentrically surround a massif or the termination of a powerful fold-zone belonging to another tectonic system, while, in the posterior part, the individual folds become somewhat divergent, and at the same time tend to turn away from the nuclear massif of the anterior part. The curvilinear arrangement of the folds roughly resembles the Greek letter η, hence the name. The folds which gather round one side of the nuclear mass in a semi-circular arrangement are not necessarily prominent, but they are always present. They may extend over a considerable area depending on the state of strain. On the other hand, the folds hemmed in between the nuclear mass and the posterior part of the system, that is, in the region on the concave side of the incurved folds, are always prominent, and they successively vary in trend to such an extent that they may almost attain a radial arrangement.

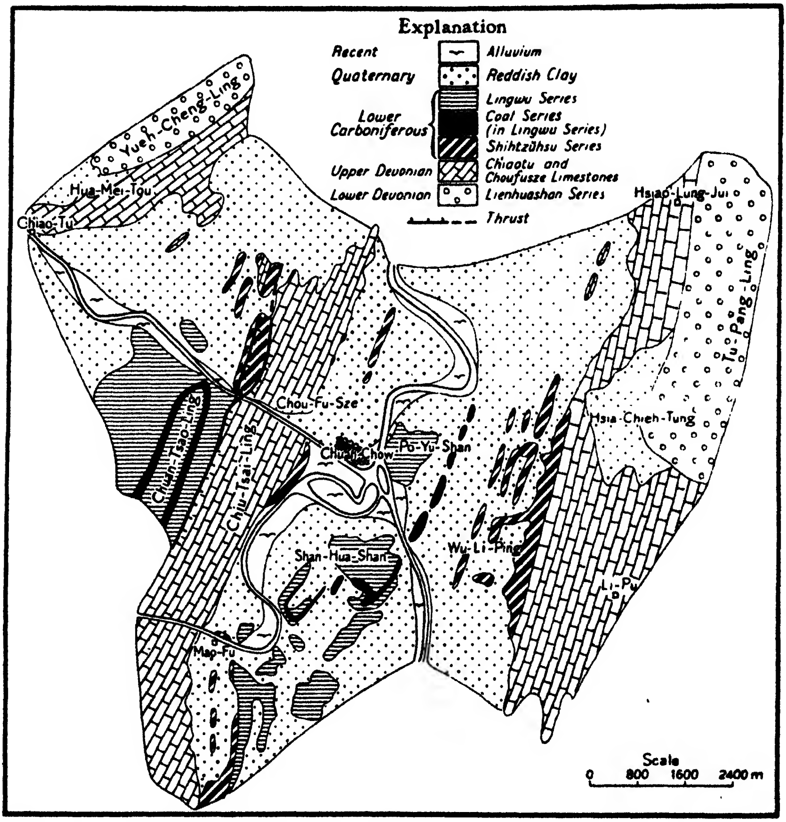

FIG. 73. Geological map of the Chuanhsien district, south-west of the Hsiang-kuei Gap, showing a part of the Wuling system of the η type. (After Y. Y. LEE.)

1. THE WULING SYSTEM

The only example of a complete η type of shear-form found in China is the one occurring in the neighbourhood of the Hsiang-kuei Gap between Hunan and Kuangsi, and embodying the Wuling Ranges. In discussing the structure of the Nanling Range we have previously noted that the middle Nanling suddenly breaks down at the Hsiang-kuei Gap, where the east-west range disappears; and in its place we find folds and mountains of altogether different trend covering the tract to the south-east of the Hsiang-kuei Gap. The mountain mass which forms the eastern end of the middle Nanling, locally known as the Changchaishan, is built up of strata which dip steeply to the north and strike east-west. Intrusive granite is exposed in the lower part of this mountain. Two important ranges radiate out from this point: one to the south-west, the Yuechengling, and the other to the south-south-west, the Pashilinanshan. Upper Devonian and Lower Carboniferous rocks are folded into a syncline between these mountains. Granitic intrusion is also observed in the Pashilinanshan. These folded mountains extend to the south-west past the neighbourhood of Chuanhsien (about 111° E., 26° N.). Between the last-named district and the main range of the Nanling several anticlines and synclines, including over-thrusts to the north-west, succeed one another. Their trend varies successively from north-north-east to east-north-east as the main range is approached from the south. They continue to spread out to the south-west of Chuanhsien, but gradually die out in that direction. The whole of this bundle of folded mountains is usually called the Yuechengling in the broader sense.

East of Chuanhsien rises the range of the Tupangling, which runs southward or slightly west of south for more than 150 km. Disregarding local variation of minor significance, the whole range is founded on a huge anticline having its axis coinciding with that of the range. The northern part of this range is simply a flat-topped, elongated dome, with Devonian sandstones and limestones broadly exposed. In the neighbourhood of the Yungankuan Pass the range is broken across by numerous east-west faults. South of the Yungankuan Pass pre-Devonian rocks, invaded by granite, form the range extending to the south of the Lunghukuan Pass for nearly 100 km. In the vicinity of Yungankuan the unconformable contact between the Devonian and pre-

Devonian formations is well exposed. There, the pre-Devonian strikes N. 40° E. and dips east at about 80°, while the Devonian strikes N. 20° E. and dips west at about 70°, showing that the Caledonian folding in that part of the range is more nearly Cathaysian, and that the later folding is quite distinct from that directrix.

The axis of the Tupangling anticline is not strictly rectilinear, but is slightly convex to the west. The westernmost point is located in the neighbourhood of Lunghukuan. From that point southward, the axis recedes to the east of south, running along the mountains between the Kongcheng and Fuchuan districts. On the eastern side of the Tupangling anticline is the Hsiaoshui syncline covering the Taohsien, Yungming, Kianghua and Fuchuan districts. East of this syncline rises another large anticline, the Mongchuling anticline, extending from the east of Kianghua to the north-north-east. In this anticline the pre-Devonian rocks are again exposed. They are invaded by granite as in the Tupangling. Both the Hsiaoshui syncline and the Mongchuling anticline are nearly parallel to the Tupangling anticline. Except for some disconcerting features occurring between Yungming and Kianghua, to which reference will be made later, all the anticlines and synclines covering the territory between the eastern end of the middle Nanling and the Mongchuling obviously form an harmonious whole. They were already developed, at least in a rudimentary form, in Hercynian times, and have undoubtedly become much exaggerated after the late Mesozoic movements. These folds represent the posterior part of the Wuling system.

The anterior part of the system is less well-developed, except in the neighbourhood of the nuclear region, which, in this case, is the eastern end of the middle Nanling. Some distance to the north-east of the Hsiang-kuei Gap we find, however, two outstanding anticlinal hill-ranges: one, located between the Lingling and Kiyang districts, is named the Huangkangling, in which the Lower Carboniferous coal-bearing series is so closely folded that the beds stand on end, and the other is the Hsiungpiling, between Kiyang and Hongchiao. In the latter range the Devonian as well as the Lower Carboniferous is thrown into an anticline. Both of these sharp anticlinal folds trend north-north-west. They bear no relation whatever to the other structural features of south-western Hunan, but are obviously in harmony with the folds surrounding the eastern end of the middle Nanling. In our definition, they represent the outer arcs of the anterior part of the Wuling system.

2. The Cordilleras of South-Eastern Asia

Another η system of much grander scale only touches the south-western border of China. It covers the south-eastern corner of Tibet, the Shan States, and Burma, and extends down to Sumatra by way of the Upper Malay Peninsula and the Andaman and Nicobar Islands. Geological exploration over the whole of this region has not been carried out to such an extent as to justify detailed discussion. Nevertheless, from what has been made known, the outline of the η type of structure is well established.

The powerful Himalayan folds suddenly terminate at the elbow of the Brahmaputra. On the northern, eastern and southern sides of the eastern termination of the Himalayan Range are compressed folds, which arrange themselves in such a way that they almost encircle the nuclear mass. In the Patkoi Mountains on the south-eastern side of the Brahmaputra the general strike of the folds appears to be north-east, becoming east-north-east towards southern Assam. Further south, in the Northern Shan States, the folds tend to open out, with their strike varying from north-east to north-north-east. Cretaceous and Tertiary beds are involved in the folding. Still further south, they turn to the south forming the Arakan Yoma Ranges in western Burma and the Shan Plateau. The former are continued to the Andaman and Nicobar Islands, and then on to Sumatra. The latter reaches the upper part of the Malay Peninsula, probably as far as the island of Puker.

A part of this system of folds occurs in western Yunnan forming noble ranges on the south-western border of China. These folded ranges are deeply incised along their general strike by the upper Irrawaddy, Salween or Lukiang, and

Lantsangkiang. Northward, the axes of these folds appear to turn round to the north-west, forming the so-called *Faisceau du Mékong*, enveloping, at a distance, the eastern end of the Himalaya. Tertiary movements have undoubtedly played an important part in raising these mountain folds, but their origin was probably much earlier.

By applying a horizontal twisting movement to a thin sheet of elasto-plastic material adjacent to a relatively immobile region in the same sheet the η type of shear-form can be experimentally produced.* The stress distribution in this case is far more complicated than in the case of the ξ type of structure. To work out the problem of stress-distribution is merely an exercise in mechanics. The point with which we are vitally concerned at present is that this type of folding involves a horizontal torsional movement which, in all probability, only affects the very surface layer of the continental mass. It is of interest to note the report from the deep cañons of western Yunnan that strongly folded strata are now and then seen to rest upon relatively undisturbed beds exposed in the lower part of the wall-like precipices. Evidence of this kind, when sufficiently explored, may eventually serve to show the shallow nature of this type of folding.

C.—THE ϵ TYPE

Of all the shear-forms developed in China the ϵ type is the most important. It consists of a group of folds in the form of a bow and arrow. The bow, or the frontal arc, resembles the compound type of that ancient weapon with both its ends slightly turned backwards forming reflex arcs. Behind the frontal arc usually spreads out an extensive plain or a relatively undisturbed region, in the middle of which rises a group of more or less rectilinear folds or a broad arch extending towards, but hardly ever as far as, the apex of the frontal arc. This part of the system is called the "backbone," corresponding to the arrow. In normal circumstances the backbone occupies the axis of bilateral symmetry of the frontal arc. But the heterogeneous nature of the land

*The readiest material would be a tablecloth or a sheet of soft blanket or a piece of wet paper.

covered by the system may prevent the bilateral symmetry from reaching perfection. The structure of the backbone largely depends on the mechanical property of the strata lying behind the frontal arc. If the strata are extremely plastic, then the backbone may altogether disappear. If on the other hand they are unusually strong then it will appear as a broad and gentle arch. The space behind each of the reflex arcs is either a basin or a plateau corresponding to the space behind the main arc but covering a much smaller area. In rare cases, the reflex arc also has a minor backbone on its concave side. Then it is called a reflex ε.

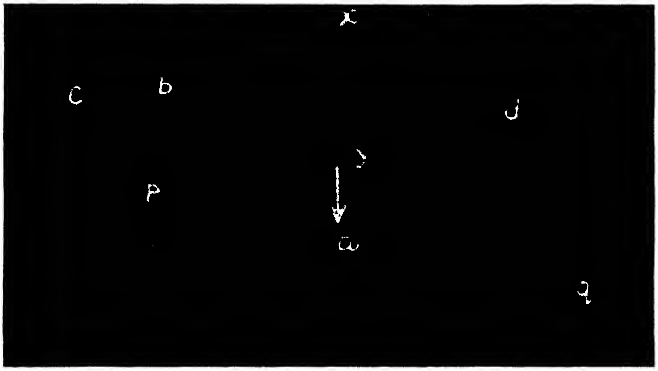

FIG. 74. A typical ε type of structure, produced on wet and moderately soft tissue paper. x y, backbone; a, apex of the main arc; c, b and d, reflex arcs; p and q, reflex ε

No less than five independent tectonic systems of the ε type have been recognized in China. They control the regional structure within the framework of the east-west fold-zones and the Cathaysian geosynclines and geanticlines. In some cases they have, however, invaded the east-west zones, modifying the latter to some extent; in others, parts of the ε system coincide with tectonic elements belonging to other systems, such as the Cathaysian geanticline. The latter fact, together with the forcible bending of the Cathaysian geanticlinal front owing to the presence of the east-west zones, has apparently led to the Suessian conception of "Eastern Asiatic Arcs." The polygenetic nature of the arcs is now well understood, and thereby we are able to appreciate even more fully the dynamic interpretation of Asiatic structure as offered by this master of geological science.

1. The Tainanlung System

A large tectonic system of the ε type is developed in northern China, comprising the Luliang and Taihang Ranges on the east, the Nanshan Ranges on the west, and the Lungshan and Alashan Ranges in the centre. The Taihang, Luliang and Nanshan Ranges represent the two wings of the frontal arc, and the Lungshan and the Alashan Ranges form the backbone of the system. On the western side of the backbone spreads out the Ninghsia Plain, and on the eastern side of it the Shensi Basin.

The eastern part of the frontal arc is largely in juxtaposition with the Neocathaysian geanticline, the structure of which has been already considered at some length. The critical features that serve to disclose the superposition of the two tectonic systems lie in the north-eastern and south-western extensions of the Shansi geanticline. It has been already noted that the middle parts of the Luliang and Taihang Ranges assume a general north-north-east trend. In the neighbourhood of the Wutaishan, the Luliang and Taihang axes become almost confluent. Thence north-eastward the conjoint axes turn to the north-east. Further north-east, the Cathaysian folds are broadly cross-folded, forming the ranges of northern Hopei and southern Jehol with their southern front almost running east-west. In these mountains where the Cathaysian geanticline and the Inshan zone cross each other, the structural condition is rendered even more complicated by the interfering influence of the Tainanlung system. That all these directrices are expressed there in one form or another is indeed a remarkable fact.

The Shansi geanticline, with its Luliang and Taihang axes approaching each other towards the south-west, merges into the Tsinling zone in southern Shensi. At the same time, the two main anticlines are accompanied on the southern side of the Taihang by more folds in northern Honan, such as those occurring in the Mihsien coalfield, and in the Hiaoshan and Hiunger Ranges. They likewise run to the south of west until they ultimately merge into the Tsinling. Thus, from the southern border of Jehol to the northern foot of the middle Tsinling, a succession of folds arrange themselves in an arcuate form, with the bulging front of the Shansi geanticline facing the south-east. They were all involved in the late Mesozoic movements. These form the eastern wing of the frontal arc of the Tainanlung system.

The western wing of the frontal arc of the system is founded on the Nanshan Ranges, which assume a dominant north-westerly strike. Towards their north-western end, these robust ranges thin down to form the Altyntagh. Instead of continuing to the north-west, the latter range turns at first to the west, and then to the south of west. This tendency to bend is in fact already clearly exhibited by the north-western part of the Nanshan Ranges themselves. Our information regarding the composition and structure of the main ranges of the Nanshan still largely depends on the observations of Obrutchev. Apart from the ancient metamorphosed sediments, probably mainly of Wutai age, and igneous intrusions, the Nanshan Sandstone and questionable Silurian and Devonian strata appear to play an important part in the building of the ranges. In places, questionable Silurian and Devonian rocks, folded into a syncline, run obliquely across the ranges. This suggests that the present trend of the mountains owes its origin, at least partly, to movements which took place long after the Devonian period. On the northern border of the south-eastern part of the Nanshan, Carboniferous sandstones and limestones, Lower Permian limestones, and post-Palæozoic sandstones are repeatedly folded and finally thrust upon altered sediments, probably of Wutai age. In the region of Sining, east of Kokonor, even the red sandstone, either of Cretaceous or early Tertiary age, is highly disturbed. There cannot be much doubt that the whole of the Nanshan Ranges as they stand to-day were involved in late Mesozoic movements, whatever may have been the effect of the earlier disturbances.

The main ranges of the Nanshan as they stretch to the south-east suffer some local deflection or dislocation in the neighbourhood of Lanchou. But the South Kokonor Range, with its tectonic axes, extends more or less continuously to the southern side of the upper Weiho until it amalgamates with the Tsinling. In these ranges and their tectonic extension we can trace the western wing of the frontal arc of the Tainanlung system. The imposing height of the Nanshan Ranges is undoubtedly due to their proximity to the elevated massif of Tibet, and therefore has nothing to do with the development of the shear-form.

The two halves of the frontal arc of the system actually join together to form a connected whole on the northern side of the middle Tsinling in the neighbourhood of longitude 107° 40′ E. Herein we find the apex of the system. The important feature to be noted in connection with this apical part of the frontal arc is the occurrence of gigantic granitic bodies to the immediate south of it. Among them the Tapeishan granite in the Tsinling Range is the most impressive. The Hanchung granite in the southern zone of the Tsinling is also located in the same longitudinal position. Its relation to the apex of the tectonic system under discussion is, however, less certain.

Slightly to the west of the longitude of the apex, and on the concave side of the arc, we find a linear series of ranges running northward. These, as we have already noted, represent the backbone of the system. The southernmost range of the series is the Liupanshan, located in the eastern part of Kansu. It may be considered as a simple anticlinal mountain faulted down along its eastern limb. Soft shales of Cretaceous age still remain at the top of the anticline. Folding of comparatively recent date may thus be inferred. This simple feature extends for a distance of more than 200 km. Older rocks are exposed in the northern part of the range which gradually subsides in that direction; but the tectonic axes continue to the north. In the neighbourhood of Ninganpao (about 106° E., 37° 30′ N.) folds involving Jurassic beds and with axes running nearly north-south have been observed by T. F. Hou and C. C. Sun.

On the western side of the upper Huangho the Alashan Range stretches to the north-north-east. This range is apparently older than the Liupanshan, and certainly far more imposing. It is chiefly composed of Sinian and older crystalline rocks with a mighty overthrust towards the east. Similar overthrusting and overfolding, involving Sinian, Ordovician, Permian and post-Palæozoic strata, are repeated in the Arbus-ula on the eastern side of the Huangho, further to the north. Still further north, the north-south axis is somewhat deflected to the north-east in the Langshan, or Kharanarinula, becoming ultimately incorporated in the Inshan zone. An area characterized by very marked disturbance and complicated igneous injection to the west of Uniusu probably marks the junction of the north-south and east-west zones. In spite of the presence of this north-south zone of strong disturbance along the upper Huangho, the vast country on both sides, namely, the Shensi Basin on the east and the Ninghsia Plain on the west, shows no sign whatever of sharing the north-south folding.

With the available data known at present, we may conclude that the Tainanlung system attained its full growth in late Mesozoic times. Its existence in a rudimentary form probably dated from the Palæozoic, and has been accentuated since. As the system grew in the course of time the backbone tended to stretch southward towards the direction of the apex. Thus we may account for the uplifting of the Liupanshan at a much later date.

2. The Huaiyin-Huaiyang System

The system under consideration is developed in place of the eastern Tsinling. That powerful east-west zone is so disturbed through the presence of this shear-form that it sweeps round to form an arc, the Huaiyang arc, along the Middle and Lower Yangtze Valley. In the western part of this arc, which is also the frontal arc of the ϵ system, the successive zones characteristic of the Tsinling structure are still recognizable; but they gradually dwindle towards the east, being partially covered by young formations and surface deposits in eastern Anhui.

The apex of the arc is located in the Kuangchih district (about lat. 31° 10′ N., long. 113° 40′ E.), south-eastern Hupeh, for west of this district the strata strike north-west, and east of it they strike north-east. Granitoid gneisses, schists and amphibolite form a broad belt in the northern part of the arc, and constitute the main ranges of the Tapeishan and Huaiyangshan. Further east they occupy a crescentic area on the southern side of the Huai Flood Plain. Sinian, Ordovician, Silurian, Carboniferous, Permian and Triassic formations appear in succession on the southern side of the metamorphic belt. They are repeatedly folded and sometimes overthrust, with the axes of the folds running north-west in the western wing of the arc and north-east in the eastern wing. The overthrusts in the western wing generally come from the north-east, but in the eastern wing they come from the south-east. Faults running across the strike of the folds are numerous. Detailed mapping carried out by T. Y. Yu in south-eastern Hupeh and by T. Y. Liu in eastern Anhui has brought out these features with remarkable clearness. Sometimes they involve considerable relative lateral movement between the adjacent blocks.

The westernmost part of the frontal arc stretches into northern and central Hupeh, where it joins the Pakang system of western China. In this region the arc tends to bend backward to form a reflex arc, or rather a series of reflex arcs all having their convex front facing the north. This tendency to bend backward is already noticeable in the westernmost part of the Tapeishan where the ancient gneisses and schists, together with a thick sequence of Sinian strata, gradually turn to the west instead of following their usual trend to the north-west. To the south of this principal zone of the frontal arc stretches out the Tahungshan anticline in which Ordovician and Silurian strata are well exposed. In the south-eastern part of the Tahungshan Range the general strike of the strata is still north-west. But from the neighbourhood of Hsiangyang to the south of Fanghsien the folds and thrusts generally run east-west. These are succeeded on the south-west by folds which show an increasingly acute bending as they close on the Huangling anticline. To the north of Ichang and west of Yuanan (about long. 111° 5′ E., between lat. 30° 45′ and 31° 30′ N.) the axis of the Huang-ling anticline is rendered almost north-south. Here lies the backbone of a reflex ϵ.

The easternmost part of the frontal arc runs between Mingkuang and Chuhsien, northern Kiangsu. In this subdued part of the Huaiyang arc the Wutai schists form low hill-ranges which gradually disappear towards the marshy land near the eastern coast.

An extensive plain spreads out on the northern side of the frontal arc constituting the Huai Flood Plain. Gently tilted red sandstone, probably of Tertiary age, forms terraces in the southern part of the plain skirting the foot of the arcuate range on its northern, or concave, side. For a long distance across this flat country to the north, nothing of the older formations is exposed, until we come to the coalfields west of Huaiyuan (about lat. 32° 35′ N., long. 117° E.), where the Cambrian and Ordovician limestones form two anticlines on the southern side of the Huai River. These are again arranged in an arcuate shape. The western anticline is overturned to the north-east and north, with its strike varying from north-west in its eastern part to nearly east-west in the western part. The eastern anticline strikes north-east with a steep limb on its north-western side. The Permian coal-bearing series is exposed all along the northern part of these anticlinal hills, and they, too, are slightly overturned. In these acute folds we see, for the last time, traces of the Huaiyang arc propagated to the north.

North of this innermost arc of the Huaiyang arcs there extends again a monotonous plain. In the Liehshan coal-field, west of Fulichih (about lat. 33° 40′ N., long. 117° E.), we begin to see Lower Palæozoic strata and the Permian coal-bearing series arching up to form hill-ranges which extend to the north-north-east. The structure of the coal-field is largely controlled by an overthrust of the Ordovician to the west-north-west. The hill-ranges mentioned above proceed almost continuously to the north-north-east for more than 60 km., until they strike against the southern border of the Shantung massif. For lack of a collective name, the writer has proposed to call them the Huaiyin Hills. The range as a whole is of a wedge-shape, narrowed down to a point at its southern end, and increasingly broader towards the Shantung massif. Moderately folded Sinian strata are exposed in the north-eastern part of the range. These are succeeded in the western part by folds of Cambrian, Ordovician and Carboniferous limestones and the Permian coal-bearing series, invaded here and there by small masses of granite. All these rocks, including the Sinian, generally strike north-north-east, but locally they strike north-east. The north-east strike is particularly pronounced on the southern border of the Shantung massif and in the neighbourhood of Hsuchow. It is also to be observed that all the synclines and anticlines developed to the south of Hsuchow have their major axes running north-north-east. Obviously the whole region was folded in the north-east trend through an earlier movement or movements. The nearly north-south trend, which controls the broader aspect of the structure of the ranges, was induced subsequently.

The Huaiyin hill-ranges represent the backbone of the Huaiyin-Huaiyang system. With the mighty Huaiyang arc in view, one is tempted to think that the western part of the Shantung massif also plays a part in the backbone of the system. The development of an extensive Cretaceous and Tertiary basin in eastern Shantung, and a general swelling up of the western massif at the same time along the line which agrees with the general trend of the Huaiyin Hills, render some support to that theory. This would eventually lead us to conclude that the last important movement which served to bring the Huaiyin-Huaiyang system into prominence took place in the later part or at the end of Cretaceous time.

The Huaiyang arc was, however, in existence much earlier. All along the front of the arc Devonian is entirely absent. On the contrary, limestones believed to be of Devonian age are present at the eastern end of the middle Tsinling. The Caledonian movement, therefore, must have forced up the eastern Tsinling region into an arcuate range, on the southern side of which were deposited the later sediments. These were again folded in Hercynian and late Mesozoic times. The most pronounced unconformities occur between the Kuhfeng Formation (Lower Permian) and the Neoschwagerina Stage, and between that stage and the Middle or Upper Permian coal-bearing series. The Rhætic, Jurassic and Cretaceous beds attain no great development on the southern side of the Huaiyang arc. As observed in the Huangmei district in south-eastern Hupeh, the Rhætic sandstones and shales with their characteristic purple colour directly overlie the Lower Permian limestone and Silurian shale. The relation between the purple series and the Jurassic has not been ascertained, but the Cretaceous tuffaceous series is undoubtedly unconformable with what it overlies.

Nor does the influence of the frontal arc of the Huaiyin-Huaiyang system end with the Huaiyang arc. The grain of the country in front of the Huaiyang arc is largely controlled by that feature. In southern Anhui, the north-east axes merge into the Cathaysian trend; in south-eastern Hupeh the whole country is affected by a series of reflex arcs which involve Cretaceous strata. These reflex arcs have their convex front facing the north. The sinuous course of the Yangtze from the mouth of the Tungting Lake to that of the Poyang Lake is essentially controlled by these reflex arcs and by the western wing of the main frontal arc.

To the south of the apex of the Huaiyang arc stands the noble mountain of the Lushan, on the western side of the Poyang. This block-mountain is divided into two parts by a powerful zone of thrusts running nearly east-west. The northern part consists of folded Sinian strata with axes running north-east. The north-east strike undoubtedly belongs to the Cathaysian, and is of an earlier generation. The east-west thrusts cannot be attributed to any geotectonic cause other than that which gave rise to the Huaiyang arc. Pressing with its apex from the north against the Lushan, the latter must have sustained a severe strain. The occurrence of large granitic bodies on the eastern side, and to the north, of the Lushan, like the Tapeishan granite occurring at the apex of the Tainanlung system, can be explained on the same ground.

The most remarkable feature attached to the Huaiyin-Huaiyang system is an exquisite reflex ϵ developed in the Nanking Hills. These hill-ranges, extending from the vicinity of the city of Nanking to the south-east of Chinkiang, are arranged in an arcuate form with the convex front facing the north. Formations ranging from the Ordovician to Cretaceous are involved in the arcuate folds, which are often accompanied by overthrusts to the north. The

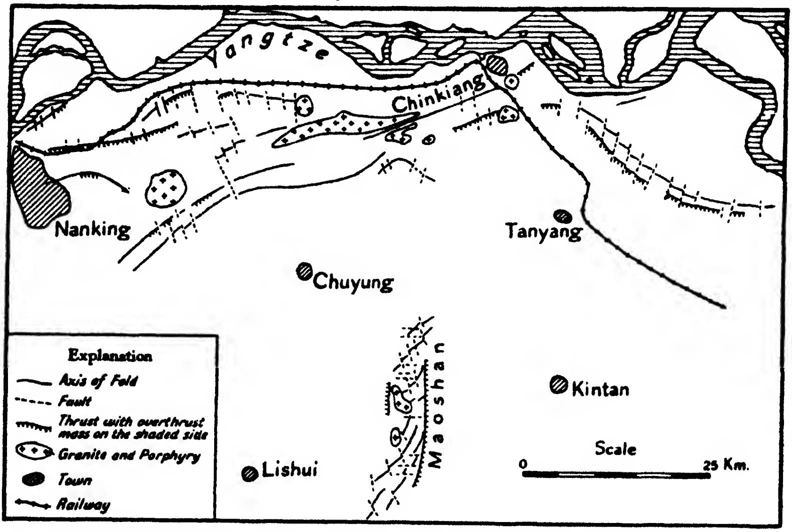

FIG. 75. A simplified tectonic map of the Nanking-Chinkiang area, showing the reflex ϵ type of structure superimposed upon the Cathaysian folds.

hills decrease in size and number towards the eastern part of the arc, but dynamic metamorphism increases in that direction. In the western part of the arc, strata up to the Jurassic are involved in a succession of compressed synclines and anticlines as well as thrusts, forming rows of hills arranged nearly parallel. On both sides of this group of hills are found tuffaceous sandstones of Cretaceous age. These are also highly disturbed, but are evidently unconformable with the older beds. Even the red sandstone, either of late Cretaceous or more probably of early Tertiary age, is sometimes thrust upon itself or upon other formations. These represent the more recent disturbances.

The older formations are by no means a conformable sequence. The unconformities between the Lower Permian limestone and the Middle Permian coal-bearing series, between the Triassic limestone and the Rhætic, and between the Rhætic and the Lias are among the more pronounced. Detailed tectonic investigation shows that after the Hercynian movement the whole region of the Nanking Hills was folded in the Cathaysian or modified Cathaysian trend, owing to the presence of the Huaiyang arc and its reflex effect. During the Jurassic movement the arcuate shape of the hill-ranges began to develop. In Upper Cretaceous times they were brought into prominence.

The eastern part of the arc is not formed by gradual bending of the axes of the folds, but by lateral tearing, step by step, of the pre-existing folds, which, in most cases, still retain the old north-easterly strike, whereas the axis of that part of the hill-range, as it stands to-day, runs south-east. The dynamic metamorphism is so strong that the limestones with embedded flints are drawn out like pastry to form an aggregate of fine fibres. Each block of the folded and metamorphosed strata is pushed a little distance to the north, as compared with the next one to the east. The northernmost point, or the apex of the arc, lies in the neighbourhood of Chinkiang where a comparatively large mass of granite is exposed.

In the longitude of the apex, and behind the arcuate range, a series of hills, the Maoshan, representing the backbone of the reflex ϵ, rises from an extensive surrounding plain. This meridional hill-range is detached from the inner apical point of the arc by about 10 km., and is itself 25 km. long. The breadth of the arc from east to west is estimated at 90 km. The structure of the Maoshan, as carefully mapped by Y. Y. Lee, is particularly illuminating. Formations up to the Triassic limestone are involved in folds with a north-east trend. At least one, possibly two, extensive and powerful thrusts, evidently of a later generation, run nearly north-south. It is these thrusts that gave rise to the north-south trend of the hills. Numerous east-west faults are also mapped running across the range. These features plainly indicate the stress condition as well as the structural history. The Cathaysian type of folding evidently covered the whole area and survived till the latter part of the Triassic. Later, the formation of the arc began with the inevitable consequence of arousing east-west compressive stresses in the strata on the concave side of the arc. Thus the thrusts running north-south resulted. Compression applied in a certain direction to a block of material necessarily gives rise, in accordance with the value of Poisson's ratio, to tension in the direction perpendicular to the compression. The east-west compression applied to the Maoshan aroused, therefore, north-south tensile stresses. Hence the east-west faults were produced. The young red sandstone and conglomerate flanking the hills are often sharply upturned and, in some cases, even reversed. The continued operation of the east-west compression in mid-Tertiary times is thus indicated.

3. The Pakang System

The system under discussion embraces the high ranges of Sikang Province, the so-called Yunnan arc, the north-western border of the Kweichow Plateau, the south-eastern part of the Red Basin of Szechuan, the Tapashan Range, and parts of the Gorge Mountains of the Yangtze. The western part of this system is still incompletely known. But the general arrangement of the structural directrices in the above-mentioned regions, so far as is known, leaves little doubt that here we are dealing with a large but somewhat distorted shear-form of the ϵ type. The distortion resulting from an intense compression offered by the Tibetan massif is particularly pronounced in the western part of the system. Nevertheless, the component elements of the system are clearly recognizable.

The western part of the frontal arc comprises the high ranges in north-western Yunnan tending to form reflex arcs as they run across Sikang to the north-west. There, the system is evidently in juxtaposition with the northern part of the Cordilleras of south-eastern Asia, of which mention has already been made. South-eastward, a complex anticlinorium is raised in northern Yunnan, forming the watershed between the Kinshakiang, or the Upper Yangtze, and the Red River. As far as is known, the arcuate axis of this anticlinorium does not everywhere agree with the axes of the local folds. This fact has given rise to a suspicion as to the real existence of the Yunnan arc. The complex structural relation between various local tectonic features is yet to be worked out; the existence of the anticlinorium is, however, beyond doubt. This arched mass represents the apical part of the frontal arc. We do not know, as yet, where the apex exactly lies, but it is believed to be located to the south of the Kunming Lakes. The slightly distorted appearance of the apical part of the arc is undoubtedly due to the presence of the powerful η system on the west. The two systems collided along the Ailao Range, on the south-western side of the Red River valley, where a belt of Archæan rocks is forced up.

At all events, in north-eastern Yunnan the strike of the folds varies from north-north-east in the inner part of the arc to north-east in the outer part of it. Proceeding from the Hueili district these folds extend to the Taliangshan Range in south-western Szechuan, and then on to the neighbourhood of the famous Omeishan, where they are cut off by the boundary fault of the Red Basin. To the south-east of these folded ranges the numerous anticlines and synclines generally strike north-east. They run along the north-western border of the Kweichow Plateau and often penetrate into the Red Basin, affecting the Cretaceous strata. On approaching the Gorge area of the Yangtze they gradually turn to the east and south-east, forming reflex arcs in south-western Hupeh.

Another branch of the eastern wing of the frontal arc sweeps round the western, northern and north-eastern border of the Red Basin. From the neighbourhood of Yaan (about (lat. 30° N., long. 103° 15′ E.), folds of metamorphosed Palæozoic and Mesozoic strata extend, at first to the north-north-east along the border of the basin, and then to the north-east past the Kuanhsien and Chaohua districts. From

Kuangyuan eastward the Jurassic beds show hardly any trace of metamorphism. They, together with the Cretaceous and Triassic, turn their general strike to the east. But they soon follow the axis of the Tapashan Range, namely south-east, as they extend eastward. In this arcuate arrangement of the folds we see that this branch of the frontal arc describes a reflex arc of a much larger size than that attached to the southern branch.

The backbone of the system is represented by several meridional ranges, located in the neighbourhood of longitude 102° E. The southernmost of these ranges is the Lungtsaoshan, extending from the Yuanmou district to the north for a considerable distance, and forming the divide between the Yalungkiang and the Anningho. It consists of schists, quartzite and metamorphosed limestones, much folded and often affected by thrusting. The general strike of the folds follows the trend of the range, namely, north-south. Some distance north of this range rises another meridional range reaching an altitude of about 7,500 m. This is the Minya Gongkar. North of this granite range a belt of Archæan rocks is succeeded by meridional folds consisting of the Wutai, Permian and Triassic strata, and extending to the latitude of 31° N. Thence northward a diversion of the meridional trend to the north-west seems to have taken place.

The Permian limestone unconformably overlies the Wutai schists, and the metamorphosed coal-bearing series believed to be of Jurassic age unconformably overlies the Triassic and the older strata. The Jurassic attains the widest development in the eastern part of Sikang Province. The fact that the Jurassic is often intruded by granites with mineral lodes, and sometimes by gabbros, indicates an important display of orogenic forces in late Mesozoic times. Long lines of fracture are mapped by Tan and Li to the west of the meridional range. They turn to the north-west as they proceed northward. Some of the fractures are probably normal faults of mid-Tertiary age, others are probably thrusts developed in late Mesozoic times. Thus we may say that the Pakang system, as it stands at the present day, was probably effected by the late Mesozoic movements.

This system departs from the normal ε type in two aspects. First, the free space behind the frontal arc is developed between the eastern wing of the arc and the median zone of folding or the backbone. This is the Red Basin of Szechuan. No such relatively undisturbed region is found behind the western wing of the frontal arc as far as we know. Secondly, the eastern wing is split into two branches. One of them is in close contact with the backbone; so much so that it might be regarded as a partial modification of the backbone. As a whole, the Pakang system exemplifies a highly compressed type of ε structure, as far as its western part is concerned. This is undoubtedly due to the presence of the Tibetan massif.

4. The Hsiangnan System

In connection with our discussion on the Wuling system of the η type we have noted that the Tupangling anticline starts from the eastern side of the Hsiang-kuei Gap, and extends for a considerable distance to the south or south-south-west. On the eastern side of this anticline is developed a broad syncline, which we have named the Hsiaoshui syncline, which assumes practically the same trend as the Tupangling anticline. Simple as this syncline is, it exhibits some complication in the mountains between the Yungming and the Kianghua districts, namely, in the Tungshankan, Tayuanling and Huangshaling, where the lower part of the Devonian formation, the Lienhushan Series, is brought to the surface. These mountains as a whole constitute a heaved-up area across the syncline, suggesting a connection with the Tupangling anticline, but belong to a tectonic system different from the η system of the Wuling.

East of the city of Kianghua rises the Mongchuling anticline, again striking north-north-east. In the south-eastern part of the Kianghua district occurs a syncline with its axis tilted to the north. Further east in the Lanshan district (about lat. 25° N., long. 112° E.) a nearly meridional syncline is cross-folded along an axis trending east by north.

The cross-folding is accompanied by intrusion of granite along the axis. On account of this cross-folding the meridional syncline is divided into two parts. The northern part has its axis pointing to the north, and can be clearly recognized from the neighbourhood of Wannienchiao on the south to the city of Lanshan on the north. The northern half of the syncline is in fact a tilted basin with its south-western, southern, and south-eastern sides surrounded by sandstones, probably of Middle Devonian age. They dip to the north-east in the western part, to the north in the neighbourhood of Wannienchiao, and to the north-west in the eastern part, forming an arc. The southern part of the meridional syncline is deflected to the south-east, with its axis pitching south-south-east to the south of Wannienchiao until it is cut off by a granite intrusion.

Throughout this area, in which the provincial boundaries of Hunan, Kuangsi and Kuangtung join one another, large masses of granite occur, cutting the anticlines and synclines and tilting them along an arcuate line with its convex side on the south. Of these, the Kuposhan and Lienshan granites are the largest. On the southern side of these granite bodies the intruded sediments often follow the strike of the elongate igneous masses, indicating that the whole region has been cross-folded with the axis of cross-folding describing an arc convex to the west of south.

Large domes with a core of granite are developed in the Hsianghualing, about 30 km. north of Linwuhsien, and Kitienling, between Linwu and Yichang. The structure in and around these domes is as complex as illuminating. To the east of the Hsianghualing a bundle of thrusts radiates out, varying in strike from north-north-east to east-north-east. Between Hsianghualing and Kitienling the whole region is closely folded, with the axes generally running north-south. These meridional folds are, however, cross-folded along the axis of the granite bodies. South of the granite all the folds pitch rather steeply to the south or south-south-east; north of it, they pitch to the north or north-north-west. The youngest formation preserved and involved in these complex folds is the Middle Permian coal-bearing series. The cross-folding is undoubtedly due to the late Mesozoic movements.

In this sweep of an arc from the northern part of the Tupangling to the Kitienling and farther east, we see, at first, that the older and younger movements generally agree in trend as far as the Tupangling is concerned. Obscure structural features begin to appear between Yungming and Kianghua, being rallied to the south-east by arcuate folds running across the meridional ones. The same phenomenon extends to the north-east along an arcuate axis whose identity can be easily traced by the presence of intrusive granite. Such igneous masses are found in the Tupangling, the Kuposhan, the northern part of the Lienshan, the Hsianghualing, the Kitienling, and finally in Yaokansien, north-east of Yichang. The Kuposhan mass occupies the apex of the distorted arc. From this mass to the Yaokansien granite the several granite intrusions are arranged *en échelon*. Their general trend of distribution is clearly directed north-east, but the individual masses often strike east-west. It appears as if the east-west axis of the Nanling Range has been torn into several parts, which are successively pushed to the south down to the latitude of the Kuposhan.

At any rate, the facts so far referred to enable us to conclude that a tectonic arc does exist along the south-western border of Hunan. This is the frontal arc of an ϵ system superimposed on the Wuling system of the η type. In the eastern extension of this arc we find numerous folds which are partially covered by the young red sandstone probably of Tertiary age, and which spread out in south-eastern Hunan. The region is not yet fully investigated, but it is known that in the neighbourhood of the Yungsing coalfield (about lat. 26° 5′ N., long. 113° 10′ E.) the folds generally strike north-north-east. Southward, they gradually turn to the north-east and even to the east-north-east on approaching the northern side of the Nanling. Thus in south-eastern Hunan, the easternmost part of the arc tends to bend backward, disclosing the characteristic feature of the frontal arc of an ϵ type of shear-form.

The backbone of the system is probably to be found in the Mongchuling, east of Kianghua; for along the axial direction of this range, and farther to the north of it, rise the Yangmingshan and Tayishan, with granite masses forming the core of the mountains. These ranges show a general north-north-east trend. If we assume that the backbone broadens out to the north, as is usually the case, we may even include in it the Hengshan and the Hsiangsiang areas, where the dominant strike of the rocks is north-north-east and where large masses of granite occur. In spite of its highly distorted nature, due to the pre-existence of an η type of structure and the presence of the east-west fold-zone, we can still recognize the essential components of the Hsiangnan system. Late Mesozoic movements have undoubtedly contributed much in bringing this system to its present salient form. Its earlier history is, however, still unknown.

5. The Kuangsi System

The greater part of the province of Kuangsi is involved in an ϵ system. Contrary to other systems of its type, the Kuangsi system interferes with the east-west zones not by its frontal part, but by its hind part. The frontal arc of this system starts from the high mountains to the north of the Wuming district (about lat. 23° 40′ N., long. 108° 15′ E.) usually called the Tamingshan. Metamorphosed Sinian and Palæozoic strata are compactly folded in this range, which as a whole describes a slightly convex front facing the north and representing the reflex arc in the western part of the system.

From the north of Wuming the main frontal arc runs south-east past the Kunluenkuan, north-east of Nanning, and enters the Linshan district in Kuangtung, where the arc reaches its apex and where intrusive granite forms high mountains. From that district eastward, the main range turns towards the north-east, being collectively known as the Chulu (Kouluh) Range, which embodies the Kiuyunling, Liuwantashan, etc. They terminate in the Yunghsien and Paklu districts in south-eastern Kuangsi. Here again the arc exhibits its characteristic reflex curvature with a slightly convex front facing the north, as against the curvature of the main frontal arc which is convex to the south. In this eastern terminal part of the frontal arc, as in the Wuming district, masses of granite have been forced up. They form the Tayungshan, Sungshan, and the mountains near Minlo. The arcuate folds are often highly eroded, and unconformably covered, in low-lying places, by the young red sandstone.

The backbone of the system is developed far to the north. It begins to appear from the north of Liuchow (about lat. 24° 20′ N., long. 109° 15′ E.), becoming quite pronounced to the south of Yunghsien along the upper Liukiang Valley. Further north, the compressed meridional folds penetrate into the Nanling Range. In the Yunghsien and Sankiang districts the Sinian sandstone and Ordovician and Silurian shales are thrust upon the Devonian formation from the west. The Sankiang thrust, which is the largest in the group, extends for a distance of more than 30 km., and strikes north-north-east.

This elevated zone of old rocks runs between the district of Yunghsien and Yipeh. Both to the east and west of this meridional zone Devonian, Carboniferous and Permian formations appear in succession. They are not lying flat, however, but are moderately folded. East of the backbone, these folded younger Palæozoic rocks vary in strike from N. 10° to 30° E. between the Yunghsien and Lungshen districts; but to the west of the backbone their strike varies from N. 10° to 30° W. when traced to the Tunglan and Linyun districts. In the district of Hochih (about lat. 24° 40′ N., long. 107° 50′ E.) thrusts again appear, where the Devonian limestone is overthrust from the south-west upon the Permian limestone. If we produce this zone of intense compression to the south-east, it will be found that it falls in line with the western wing of the frontal arc. In fact, the whole region of north-western Kuangsi seems to be dominated by north-westerly directrices. They tend to turn westward as they stretch farther to the north-west.

The structure of north-eastern Kuangsi is controlled by north-easterly directrices, as has been already noted. But the presence of the η and ϵ structural types on its eastern side has affected the general trend of the folds to some extent. The reflex tendency of the curved axes is no longer noticeable.

The characteristic feature about the Kuangsi ϵ is that a continual succession of folds is propagated from both sides of the backbone. The free space is only restricted to the region immediately behind the frontal arc. Continual variation of the trend of the folds on both sides of the backbone rather reminds us of the type of structure so graphically described by E. Argand under the designation of "virgation du premier genre double." It must, however, be emphasized in the present case that the median zone of the double virgation is distinguished from the rest of the series of increasingly divergent folds by the swelling up of old rocks and by the prevalence of excessive compression.

So far as the stratigraphical evidence goes, the Kuangsi system was brought about by a movement of post-Triassic and pre-Tertiary age. Later disturbances have, however, exaggerated the system of folds already laid down.

6. The Amur System

One more tectonic system probably of the ϵ type deserves special notice, inasmuch as it peculiarly falls into the position corresponding to those of the Huaiyin-Huaiyang and Hsiangnan systems of eastern and southern China respectively. This is the Amur system. It will be recalled that the Huaiyin-Huaiyang system is developed at the expense of the eastern Tsinling, and the Hsiangnan of the eastern Nanling. This system is similarly developed to the east of the Tannu-Kentai zone. Little as we know of the structure of the Little Khingan Range standing on the southern side of the Upper Amur, there is hardly any doubt that its general structural axis runs south-east in the western part, but gradually turns to the east as it follows the course of the Amur River. Further east, it merges into the folded ranges on the north-western side of the Shikotan-Alin Mountains trending north-east. There should be a backbone on the concave side of this frontal arc. Judged from the tectonic map of North Manchuria compiled by E. E. Ahnert, such a backbone appears to exist between longitudes 132° E. and 134° E. Like those of its corresponding systems in eastern and southern China, the backbone of the Amur system points not due south but to the west of south.

The ε type of shear-form can be experimentally reproduced by applying a horizontal shear upon a thin sheet of elasto-plastic material which adheres to the floor with a slight viscosity. The median zone, namely, the tract containing the backbone and the apical part of the frontal arc, is the region which is to undergo maximum shearing movement. The amount of relative movement decreases from the median line of the system towards both wings of the frontal arc; the direction of movement of the region behind each reflex arc is reversed in the relative sense. In other words, the whole process is accomplished by a differential horizontal movement of a region against two tracts of land, one on each side, which more or less firmly adhere to the floor. These relatively immobile regions are those which lie behind the reflex arcs.

The stress condition in the sheared sheet can be easily deduced by considering it as a thin beam loaded uniformly and supported at both ends. When bending takes place, tensile stress will be set up on the convex side and compression on the concave side along the length of the beam. There will be a neutral zone within the beam, which marks off the compressive from the tensile zone. In the ε type of structure as it occurs in nature, the neutral zone probably lies behind, but not far removed from, the frontal arc. The tensile stress set up in the arc is released partly by elongation along the axial direction of the folds forming the frontal arc, more or less in accordance with Poisson's ratio, and partly by fracture near the apex, where, as we have already seen, granitic intrusion usually abounds. The compressive stress aroused far behind the frontal arc is responsible for raising the backbone.

Experimental evidence tends to show that, if the material is too plastic or too thin in comparison with the size of the sheet, then the backbone would not appear as a single ridge or fold, but would be replaced by a series of folds which radiate out from the space behind the middle part of the frontal arc. They become more and more conformable in trend with the two wings of the frontal arc as they spread out towards both sides of the system.

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CHAPTER VIII

TECTONIC TYPES AND THEIR RELATED EARTH MOVEMENT

General Considerations

In recent years speculation has wandered far into the domain of dynamic geology. Each school of thinkers tries to enforce its view through some narrow channels of logic that do not always take sufficient heed of the arrangement of the ancient and existing mountain ranges brought about by orogenic forces. An investigation in which we are primarily concerned with geotectonic phenomena has sometimes curiously left tectonic geology out of account, except for certain broad features of continental scale that are now and then appealed to as corroborating evidence. In this brief treatment of the subject it would be too pretentious to discuss the merits and demerits of the various hypotheses regarding the origin of earth movement, but attention will be focussed on the more important structural features and the records of the oscillation of sea-level in the past. The latter aspect of the problem has been incidentally alluded to in connection with our discussion on the repeated marine floods over the Cathaysian geosynclines and the adjacent areas. From these basic facts an attempt will be made to deduce the logical consequences arising therefrom. Special consideration will be given to the structural pattern of China not only because of the natural requirements of the present work, but also because of the clear development of certain outstanding tectonic types that are not always clearly revealed, for one reason or another, in other continental areas.

Before, however, entering upon a discussion of the mechanics of such tectonic types and the rhythms of oscillation of sea-level, a few remarks must be made on some fundamental conceptions of earth movement. Theoretically, all movements, either of the land or of the sea, must be considered as phases of secular movement. There seems no way to avoid the issue that these are to be treated as mutually connected events. But the methods of approach to these diverse aspects of the problem should obviously differ from each other from the dynamic point of view.

The oceanic body is a fluid, devoid of strength. Its behaviour in a given field of force must therefore depend on the laws of hydrostatics. The continental masses on the other hand possess a definite strength with definite elastic or elasto-plastic properties. There is as yet no convincing evidence to show that gigantic masses of rock can behave entirely as fluids under long-continued stress. Even if we grant this assumption (that rocks may yield to any long-continued stress, however small), owing to the uncertain factor of time in human experience the question is ultimately reduced to one of elasticity versus that of plasticity. Thus the problem can be formulated without involving the uncertain element of time.

From the practical point of view it is exceedingly difficult to distinguish between movement of the sea and movement of the land. When folds or other tectonic disturbances occur, the geologist can tell us at once that at a certain place and perhaps at a certain time, if the stratal records are nearly complete, a movement on the part of the land took place. But as to the transgression and regression of marine water, the question is far more complicated. What the geologist sees is only the relative movement between land and sea, or the net result of movements thereof. In a particular case that result may be brought about in a number of different ways and under different circumstances, which we shall consider when we come to deal with the movement of marine water.

As to the movement of land-masses there are certain points that require preliminary consideration, because thev are often neglected by those who care so much for the trees that they are apt to forget the wood. As geological observers we are told to look for the axis of a fold in the field. When we succeed in establishing the axis of the fold, especially when the fold is of the recumbent type, the assumption at once follows that the pressure came from the direction perpendicular to the axis, and originated from the side on which the anticlinal fold tends to override its synclinal counterpart. This assumption is especially prevalent when a thrust appears. Upon this assumption usually rests another assumption that the movement came from the overriding side. Some geologists even go so far as to consider these assumptions as unquestionable truth. If we follow the elementary principles of mechanics, as we have to do in treating matters of this kind, it will be realized that long gaps are left open in this succession of thought. The nature of the external force applied, the direction of the regional movement, the mechanical properties of the strata, the induced stress-system and the resulting deformation, all offer distinct problems whose solution requires careful adjustment in order to produce a logically connected whole. When we apply the same set of forces upon different material systems the induced stress-systems will be necessarily different. And it is the stress-system that conspires to deform the strata involved. The direction of the regional movement, or the external force that urges the movement, does not necessarily agree with the particular system of stress that is responsible for the local deformation.

The logical analysis of geotectonic phenomena must therefore begin with a detection of the expended stresses. We have no means of knowing the original stresses which prevailed; we do know, however, the deformed crustal features produced by them, if they exceeded the limiting strength of the strata. A set of related structural elements forms then a strain-figure which is the record of the stresses that once produced it. From the individual structural elements we can hope to know the distribution of stress; and from the distribution of stresses thus ascertained we can obtain some idea as to the nature of the stress-system. A stress-system brought to light by some such method, coupled with a knowledge of the mechanical property of the strata, would offer us some definite information as to the nature of the regional movement or external force applied.

The validity of our interpretation of geological structure in terms of geodynamics would thus seem to depend upon our effective recognition of the nature of the stresses relieved through the structural elements which resulted therefrom. There is not much difficulty in carrying out this part of our work, for in the ultimate analysis of a stress-system we can always come to the direct stresses, tensile or compressive. By synthesizing tension and compression at right angles, we know the direction of shearing stress. These are elementary rules of mechanics which need no further comment. The stresses to which a given rock-body has been subjected are conceivably much more complex. They may be revealed, to some extent, in the so-called tectonites, that is, in the optical orientation of mineral grains, or in cleavages, joints and miniature folds. The subject is being explored by Sander with some initial success as far as micro-tectonics are concerned. As regards the tectonics of minor features Hans Cloos has already made valuable contributions. Unsparing effort is being made by a continental school of geologists to develop the subject.

In dealing with the structural plan of a continent, or the horizontal pattern of extensive sheets of deformed rock material, we are fortunately not confronted with the formidable intricacy of the stress-systems. The simple stresses that we have just referred to, namely, compression, tension, and shear, are all expressed by specific types of structure. These seem to carry us far in any inquiry into the direction of regional movement. We recognize certain extensive zones of horizontal compression and tension, and numerous structural forms due to horizontal shear. In a strict sense, simple direct stress is probably non-existent in the crust of the earth. In the mechanics of the earth's crust, we have nearly always to deal with stress difference, and consequently with shear.

As simple and obvious examples we have "disharmonious folds," nappes, or schuppen structure to indicate shear occurring at all angles with the horizontal plane, and normal faults to illustrate vertical shear. Indeed, we may regard shear as a universal phenomenon in connection with all forms of deformation of the earth's crust. Even the extensive zones of compression and tension are not unaccompanied by shear; for, in the extensive folded ranges, the compression cannot occur without inducing shear in the lower part of the strata thus displaced; nor is it conceivable in the development of rift on the theory of tensile origin that the whole body of our planet was torn open without any differential horizontal movement between the upper and lower parts of the earth's crust. A complete investigation into the sheared condition of the surface layer of the earth would therefore necessarily involve analysis of strain-figures in three dimensional space.

Comparing, however, the thickness of the upper layer of the continental crust, as deduced from seismological evidence, with the size of the continents, it is to be freely admitted that the former only occupies but a most minute fraction of the latter. And there is no reason to assume that all horizontal movements affect the entire thickness of the upper layer of the continental masses. On the contrary, evidence is sometimes available that folds which we observe on the surface are not shared by the more deeply seated strata. For lack of space, unfortunately, we are unable to refer to the actual cases bearing on this important issue. At any rate, we are not seriously concerned at present with such evidence. The fact to be emphasized is that almost all the major strain figures developed on the surface of the earth, with the exception of large normal faults, can be explained on the basis of concerted operation of stress-systems contained in the horizontal plane.

For this reason, our method of attack can be greatly simplified. The first and most important step is to trace out the strain-figures in the horizontal plane by co-ordinating the surface features of which we have direct cognizance. If such figures could be satisfactorily established by appealing to first rules of mechanics, then they would have to stand for the horizontal plane. A similar procedure might be successively applied downwards, using, all the time, the available sections as our guide or check. In this way the third dimension, the vertical, can be duly explored. Inferences as to deeper conditions thus arrived at should not, and cannot, upset our conclusions derived from actual observations on the surface, if those conclusions are based on sound mechanical principles.

Thus, the crucial test of our method must rest on the efficacy of our analysis of the surface features with reference to the horizontal plane. Mention has been made of specific types of structure as expressions of earth-stresses. A fold or a group of folds and thrusts is usually attributed to compression, and cross-faults or tear-faults to tension. But these are not all. There are several other types, none the less important, that arise from a combination of compression and tension. Each of such types signifies a shear of a particular kind. Each type bears some characteristics in the arrangement of the elemental folds and faults that constitute the whole tectonic system. They are here called shear-forms. The dominantly compressive and tensile zones, together with the shear-forms, represent the important categories of horizontal geotectonic types that offer the clue for the solution of the geodynamic problem. The comparatively "stable" tracts, such as massifs, shields, plateaux and extensive basins, appear to be incidental to the development of these "labile" zones. Proceeding from this point of view, the origin of the stable tracts would be a problem largely bound up with that of the genesis of the deformed zones.

As to the arrangement of the labile zones, it has been the usual practice either to group together, according to personal discretion, certain structural elements that do not necessarily belong to one system, or to divide one system into several elements. The only reliable criterion so far accepted is the contemporaneity of the different elements. That criterion is necessary, but not sufficient. Here again, we must refer to our assertion that, having established the chronology of a group of tectonic features, the only assured method of systematizing them is to follow their distribution in accordance with the requirement of mechanical principles.

In practice, however, it is not necessary to go through the whole length of theoretical consideration in each case. From field experience we have already established certain standard types, each having some characteristic features generated by particular sets of stresses. All that we need to do is to compare a given group of features with the established type. If the component elements are found to agree with those in one of the standard types, then the probability is high that they were produced by similar processes. If, on the other hand, they are found to be unique in arrangement, then a thorough investigation is needed as to the stress condition in order to justify the establishment of a new type.

The conception of tectonic types, as treated in the present work, may be epistemologically compared with organic forms and rock-types. The method of their determination can proceed on similar lines. In organic forms we have certain outstanding morphological characters of known groups to serve as our guide for natural classification, and for rock-types the mineral constituents and textures afford useful criteria. In the latter case we can even appeal to synthetic experiments. Our tectonic type with its salient features can almost be compared with a " form-genus " or a rock-type, if we find it repeatedly occurring in the continents and if further we understand its mechanical significance, either by experiment or from theoretical considerations based on mechanical principles, just as a claim to complete understanding of a rock-type would be based on a knowledge of physico-chemical conditions. The confluence of two independent magmas produces a hybrid type of rock. Similarly, the conjugation of two tectonic types produces a syntectic type of structural form. Rocks are metamorphosed through mineral and textural transformation. So also a tectonic type may be modified through the alteration of the component features. Heat, pressure and chemical composition are the principal factors that determine the whole fabric of rocks and their metamorphosis. Compression, tension and shear, together with rock composition, are the determinative factors in the original arrangement and subsequent variation of tectonic types. It is not necessary to explore this parallelism any further. The point that seems to deserve emphasis is that tectonic types in the domain of tectonic geology may well claim as important a status as rock families in petrology. The few tectonic types that we have already described are even more readily understandable as to their genetic history than most of the rock-types.

It has been repeatedly pointed out that an overthrust mass does not necessarily indicate the direction of regional movement. In an overthrust zone, as in a highly folded zone, we only know of compression. The directional movement of the rock-mass in space is another matter. The factors determining overthrusting or underthrusting are probably connected with initial unequal distribution of mass in the vertical sense and the mechanical properties of the strata. The direction of movement achieved by any part of the rock-mass is only relative. In the same way, a horizontal shear-form determines only the relative movement between the adjacent tectonic units. When, however, a number of such forms occurs over large parts of continental areas, then in their assemblage the general tendency of continental movements becomes obvious with reference to some co-ordinate system having its origin placed at the centre of the earth or at one of the poles.

General consideration along these lines enables us to grasp the essential structural features of eastern Asia from their genetic point of view. The subject is vast and complex when pursued to the logical end, but for our present purpose it is hardly necessary, indeed not possible, to deal with detailed features of secondary importance. As to the broader features, their development in time and their distribution in space usually furnish sufficient data to warrant their independent existence as discussed in the foregoing chapters. Extensive zones of horizontal tension do not appear to exist in eastern Asia. On the contrary, broad and extensive zones of compression and shear are of frequent occurrence. The extensive zones of compression of first tectonic order are dealt with under the categories of Cathaysian geosynclines and geanticlines; the east and west tectonic zones and the horizontally sheared sheets are treated in different types of shear-forms. It should be noted here that, as already discussed in connection with their actual occurrence, faults associated with the sheared sheets are not due to pure tension, and fractures occurring along the foot of extensive mountain ranges or in uplifted tracts are merely due to the operation of gravity, probably arising, at least in some cases, from isostatic adjustment. Neither of these can be regarded as evidence of pure tension, as is sometimes advocated. Even the extensive zones of compression constitute only a special type of shear in which a whole section of a continent takes part along a more or less rectilinear front. We shall return to this point when we come to discuss the mechanism of continental movement as a whole in the light of experimental evidence.

Although the natural history of each of the three classes of tectonic types developed in eastern Asia is fundamentally independent, a tectonic system belonging to one class sometimes interferes with another that belongs either to the same or to another class. The mutual interference may be brought about by simultaneous movements, or by movements in successive orogenic epochs. The result is to produce either syntectic or superimposed types. On account of such mutual interference between the various tectonic systems in adjacent regions or in superposition upon one another, it is often somewhat difficult to distinguish one tectonic type from another unless the stratigraphical record happens to be so complete that no uncertainty is involved in their chronology, and unless the nature and orientation of the one type is so markedly different from the other that their independent existence is self-evident.

More often, however, the stratigraphical record is far from being complete, especially in old mountain ranges, owing to partial or complete removal, through prolonged erosion, of any deposit that may happen to have been formed after each episode of movement. Repeated attacks of orogenic forces along similar lines further lessen the chance of preservation of the older deposit in such highly disturbed zones. In the case of "posthumous folding" the difference in the amount of dip between the successive formations may be so slight that it can easily evade observation, even if the several formations involved are all preserved. These practical difficulties have often led to the assumption that those phases of earth movement that are clearly recorded in the preserved sediments are the sole episodes of movement which have actually occurred in a given zone of deformation. Destruction of evidence by nature is a fact against which we are not always on our guard.

Nevertheless, a feasible method of approach to the problem can be applied along two independent lines of inquiry. Firstly, observations along the borderland between the relatively stable tracts and the folded zones, together with palæogeographical reconstructions, usually serve to disclose the evidence of a land-barrier across the epicontinental sea, or give evidence of folding which occurred in a definite epoch that can be compared with one of the well-established orogenic epochs in other parts of the world. The evidence thus obtained may be somewhat indirect, but none the less conclusive.

Secondly, an appeal can be made to the mechanics of tectonic types. If in the normal development of a tectonic type we can satisfactorily establish its component elements, then we cannot seriously err in correlating a certain part of a tectonic system of known date with those other parts of the same system of unconfirmed age on the ground that they conform with the normal type. Ultimately we shall be led to face Stille's contention, namely, "Zeit Gesetz," or synchronism of earth movements in various parts of the world at a given geological time, however reluctant geologists may be in accepting that sweeping rule in its full sense. For the time being we need not invoke Stille's "law." A recourse to these two lines of investigation usually suffices for each individual case.

The latter method of approach is even more important, if not indispensable in some cases, in dealing with continental structure, particularly the structure of eastern Asia; for in that area so-called posthumous movements have often been repeated more than once in one and the same mountain zone since early geological times. Only in favourable instances are such movements recorded in preserved sediments. Mountains arose and subsided along the same sites or in their proximity with essentially the same trend as they stand to-day. A new set of mountain folds with a distinctly different arrangement only rarely arises out of the sites of the old and peneplaned mountains. In fact, so far as China is concerned, the more obvious cases of this description are only known in the Nanling Ranges. This state of affairs, which may be called the permanence of orogenic zones, is a phenomenon not confined to the eastern Asiatic continent, but appears to be more or less characteristic of all the continents. The diversified development of the mountain systems of north-western Europe in the course of geological time seems to be an exception rather than the rule.

Facial Traits of the Earth and their Dynamic Significance

We have already seen that the Palæocathaysian geosyncline and Palæocathaysia were already in existence in Sinian times. They persisted with minor modifications down to the end of the Ordovician, and possibly to the end of the Silurian period. The Mesocathaysian geosynclines and geanticlines were developed out of the Palæocathaysian geosyncline and geanticline. The Triassic and Jurassic troughs of eastern Asia were in fact " sequent " geosynclines, to use the terminology of Schuchert. Neocathaysian geosynclines and geanticlines are direct descendants from the Mesocathaysian. Whatever may be the minor differences among this series of features, they all agree in one important respect, that is, they all assume a north-easterly trend. In other words, they run parallel with the continental border of eastern Asia.

Reasons have been given to show that these grand synclinoria and anticlinoria cannot be regarded as features resulting merely from vertical subsidence and uplifting, but were brought about by lateral pressure. They are gigantic folds involving possibly the whole thickness of the continental mass. It is quite obvious that the pressure was exerted by the continent towards the Pacific, or vice versa. On this point nearly all geologists agree, though some would insist that the pressure originates from the land, and others from the ocean floor. We have no right to cling to one point of view any more than to the other, so long as the synclinoria and anticlinoria are treated *per se*. The issue must be decided from evidence derived from other sources.

From the study of the structural details of the Cathaysian area, we have found that the region is covered by the ξ type of shear-form. The orientation of this shear-form forces us to the conclusion that the Cathaysian region has been subjected to compression perpendicular to the continental border, and that this compression has been induced by a southerly movement of the continental mass against the Pacific floor, or by the latter moving northwards against the continent. Here again we are up against the same difficulty in making our choice. No choice can be made at the present stage. What we do know, however, is the fact that relative north-south movements have taken place intermittently between the eastern Asiatic continent and the Pacific floor since Sinian times.

The nearest allies of the Cathaysian geosynclines and geanticlines are the Appalachian geosyncline and Appalachia. These latter features border the eastern North American continent, and, like their parallels in Asia, run north-east. The geosynclinal part is known to have undergone several severe tectonic disturbances during Palæozoic times, but the general trend of the synclinoria and anticlinoria persisted. Some of the troughs may have survived till Triassic times, as shown by the presence of fresh-water red deposits of that age. Even in more recent geological times signs of tectonic disturbance along the Appalachian zone are not wanting, although they are only to be found in the renewed uplifting of the mountain blocks and a certain amount of igneous activity near the coast. Two reasons may be offered to account for the apparent cessation or diminution of pressure against the Appalachian zone in later ages. Firstly, the mountains are over-grown, and the deformed strata are set. One cannot expect folding along the Appalachian axes to take place in the strata which are already compactly folded and overthrust, even if they continue to receive pressure from sources similar to those which gave rise to the disturbances in Palæozoic times. Secondly, the apparent diminution of pressure may be real. We shall offer an account later as to how the relief of pressure might be brought about.

In geological literature one often finds the unfortunate expression, the " Pacific type of coast." In this expression it is apparently implied that the Pacific coast is of the Cordilleran type. There are no true Cordilleras in eastern Asia. If we choose to compare eastern Asiatic structure with the American, the similarity is to be found between Cathaysian and Appalachian as we have discussed above, and not between Cathaysian and Cordilleran. The high mountains in the Philippine Islands, such as the Sierra Madre, the Cordillera Central, and the Zambales, with several arcuate axes curving into them from the south-west, do suggest the Cordilleran structure of South America; but they are of limited extent, and can by no means represent the type of structure of the island festoons further north. Even the " Cordilleras of Australia " have proved to be but a series of pre-Mesozoic folds trending north-north-west with a relatively steep limb on the western side. Mesozoic and later folds in the eastern part of Queensland are comparatively gentle and local. They are not spread all along the coast as in true Cordillera. The main structural features of New Zealand represent a syntectic type of its own embracing the Australasian arc, the " Southern Alps," and their north-eastern continuation. Again they cannot be considered as true Cordillera. The only group of structural features in Asia that may be compared in kind and in grandeur with true Cordillera is that chain of mountains which stretches from the eastern end of the Himalaya down to Burma, the Andaman and Nicobar Islands, Sumatra and Java. They face the Indian Ocean on the west, but not the Pacific on the east. We shall return to these features later.

Of all the tectonic types developed in eastern Asia, the east-west fold-zones are the most striking and baffling.

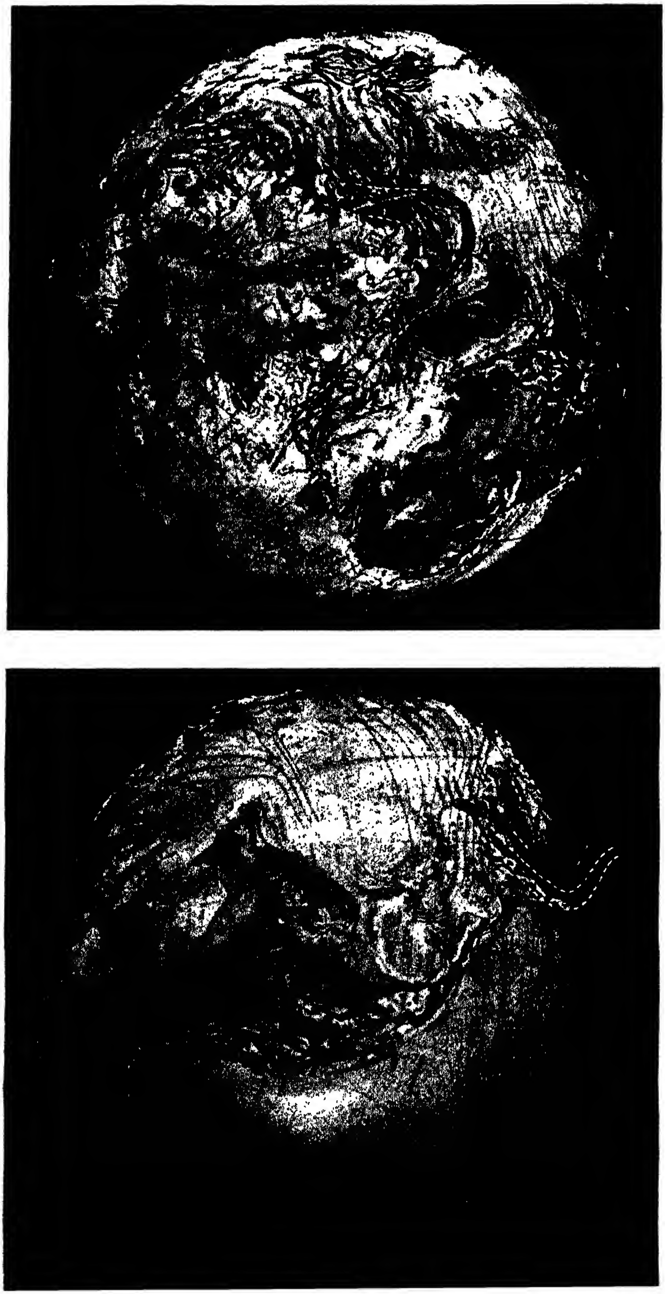

FIG. 76. Major structural pattern of the northern Hemisphere, with broken lines showing the approximate position of the different tectonic systems belonging to the ε type and thick lines showing east-west tectonic zones.

They are all clearly due to compression directed north-south. The large boundary faults sometimes found along the foot of the east-west ranges are fractures consequent to the uplifting of the mountain masses. Their origin, whatever might be the proper explanation, cannot, in any way, throw any light upon the origin of the pressure required to produce the folds and thrusts. Amazing is the fact that, as far as we know, the east-west zones have had a prolonged history, and are distributed at nearly equal intervals, that is, they are separated by about 8° of latitude.

Starting from the north, we have the Angara zone extending probably from the eastern side of the Yenissei horst along the middle course of the Angara River where it flows westward to the source of the Lena. Further east, the east-west zone is somewhat disturbed by the Vitim Plateau, a reflex arc of the Irkutsk system of ε structure. East of the Vitim Plateau, a formidable east-west range again appears running across the Upper Olekma, Tympton, and Aldan, until it comes to the Utschur Valley and the upper course of the Seya, where the east-west axis gives way to the north-north-east directrix of the Cathaysian type. Apart from local variation, this " Alter Scheitel " of Siberia maintains a general east-west front, with folds of Archæan schists and gneisses stretching in the same direction. The folding in the main range was probably accomplished in Pre-Cambrian times. But, on the border of the Alter Scheitel, formations believed to be of early Palæozoic age are also folded. Information is still too meagre to justify a detailed discussion.

On the southern bank of the Angara, Archæan schists are thrust to the north over folded strata of Jurassic age. Similar features evidently extend for some distance both to the north and south of the valley. They all strike nearly east-west. As a whole, this Siberian east-west zone is located in the latitudes of 57° to 58° N. The western termination of the Aleutian arc is probably controlled by this zone, as all the island festoons are by other east-west zones.

The Tannu-Kentai zone is pierced, so to speak, by the frontal arc of the Irkutsk ε. The latter thrusts into this east-west zone, which is made to form an arc in its middle part represented by the Khangai Mountains. This relation explains why the western members of the Khangai Mountains more or less conform with the Sayan, and the eastern with the Transbaikalian trend. Apart from this disturbance, due to a feasible cause, the Tannu-Kentai zone is, as a whole, located between the latitudes of 49° and 50° N. Folding along this zone is known to have occurred in pre-Sinian, Caledonian, perhaps Hercynian and late Mesozoic times. On the west the zone gives way to the grand arcs of Eurasia belonging to the Eurasian system of the ϵ type, and on the east it is partially replaced by the Cathaysian directrices.

In western Europe, outside of the Eurasian arc, we find the Armorican zone cropping out in southern England and Brittany. In south-eastern England, this zone is continued underground, *e.g.*, in the Kent coalfield; it reappears at the surface in central Belgium. As it enters northern Germany, the great sweep of the Eurasian arc has wiped it out of existence. It is a well-known fact that during the Hercynian disturbances intense folding and thrusting took place along this zone. In mid-Tertiary times folding along the east-west axis was again manifest. The best example of such folding is found in the Isle of Wight. Its latitudinal position is approximately equivalent to the Tannu-Kentai zone of eastern Asia.

In the North American continent a fragment of this zone is perceptible in Newfoundland, joining on to, but lying outside of, the Appalachian folds. The fact that the east-west zone does not penetrate into the interior of North America may be accounted for by the same reason as that which explains the absence of the east-west zones in the interior of the Eurasian arc.

The Inshan zone is located in the latitudes of 41° to 42° N., being replaced towards the continental border of eastern Asia by the Cathaysian directrices, and cut off by the Eurasian arc on the west. Owing to the presence of the Tibetan massif further south, its western part is evidently dislocated and shifted, as it were, slightly to the north. We have traced its existence back to the Sinian period. Powerful movements broke out all along this zone in late Mesozoic times. In the western part of the Eurasian continent we find the Pyrenean zone stretching along comparable latitudes. It is a well-known fact that the present Pyrenees Mountains rose in mid-Tertiary times. Recent research in the eastern part of that range has, however, brought out the important fact that it was likewise affected by the Hercynian movement. We must realize that in a folded and refolded range of that kind the task of disentangling the earlier and later movements is not at all an easy one. And in places where prolonged geological periods are represented by a stratigraphical break, repeated folding may remain for ever unknown.

This same zone of east-west trend appears in the Boston Basin where intense folding coupled with thrusting characterizes its structure. The folds and thrusts all strike east-west, having nothing to do with the general trend of the Appalachians, in spite of the fact that it comes so close to them. Indeed, the Appalachian chain is locally deflected to the north-west of New York from its normal north-easterly trend, for which we cannot find any feasible cause other than the presence of the east-west zone. Palæogeographical research leads Grabau to believe in the existence of an "Albany Axis" across the Appalachian geosyncline back in Cambrian times. This alleged faunal barrier may have had a tectonic origin. Its latitudinal position certainly corresponds to that of the Boston east-west zone. If they belong to one and the same zone, it would follow that here the east-west zone has actually penetrated into the Appalachian directrices. The same is true of the Inshan zone which penetrates into the Cathaysian geosyncline.

The Tsinling zone which is located in the latitudes of 33° to 34° N. finds its duplicate in the Mediterranean Atlas Mountains on the western side of the Eurasian arc. The pre-Tertiary history of this range still requires further research. Across the Atlantic, the Ouachita zone of Arkansas and Oklahoma is located in about the same latitude. The existence of a geosyncline in the neighbourhood of this zone almost throughout the Palæozoic era, as mapped by Schuchert, presupposes the presence of a geanticlinal feature associated with it. The important Laramide movement along this zone reminds us of the intense folding and thrusting that occurred in the Tsinling zone towards the latter part of the Mesozoic era. It remains to be demonstrated whether the curious bending of the Cordillera to the north of Santa Barbara, Los Angeles, and San Bernardino is in some way connected with the presence of this east-west zone.

The Nanling zone is located in the latitudes of 25° to 26° N. Nowhere else in the Northern Hemisphere do we find an east-west zone developed in this latitudinal position, except in the desert region of western Africa where, according to Gregory, there exists an elongated east-west valley "due to early folds." On the other hand, two important east-west zones are found in the latitudes of 25° to 26° S. One of these is that extraordinary igneous basin of Bushveld, running between Johannesburg and Pretoria with enormous outpouring of sial as well as sima material. The region was probably "updomed," according to R. A. Daly, already in post-Ventersdorp times. Folding of some importance occurred in post-Waterberg and pre-Karroo times. Renewed igneous activity in post-Karroo times suggests still later movements. This zone of igneous complex, together with the tectonic zone prolonged towards the west, extends for nearly two-thirds of the width of that part of the continent.

The other occurs in Western Australia, stretching from the headwaters of the Gascoyne to the north-western end of Lake Carnegie. Across this desert land steeply folded beds of conglomerates, sandstones, quartzites and phyllites of the Mosquito Creek Series, believed to be of Pre-Cambrian age, rise to form hill-ranges generally striking east-west. The Nullagine beds which overlie this series are also moderately folded, generally along the east-west axis, as the zone is approached. If it be proved that this zone extends to the Warburton and Musgrave Ranges, it would mean that this east-west zone runs across nearly half the width of the continent.

In the Southern Hemisphere, we find another east-west zone developed in the neighbourhood of latitude 34° S.

This is the Cape Fold Range. The eastern part of this zone has broken down, and its western termination is to some extent disturbed by another tectonic system. The beds involved are not so highly folded as those in the other east-west zones already mentioned. If, however, we compare them with those forming the Karroo Basin on the north, the display of orogenic force along this zone is obvious. In latitudinal position, the Cape zone corresponds to the Tsinling, Mediterranean Atlas, and Ouachita of the Northern Hemisphere. It may be noted that nearly all the east-west zones of folding belong to the class of *pli de fond* or *Grundfaltung* (deep-rooted folding).

The importance of such east-west zones in their control over the tectonic pattern of eastern Asia cannot be overemphasized. We have already noted that all the island festoons terminate at points where the east-west zones reach the continental border either actually or virtually. We have regarded the festoon islands as a semi-submerged geanticline standing on the border of the continent. Inside this outermost Neocathaysian geanticline is a long stretch of shelf sea. Further inland rises another long series of geanticlines arranged in linear succession. They are again divided by the east-west zones into several parts, each crudely conforming with an island festoon. The Great Khingan corresponds to the Kurile Arc, the Taihang to Honshiu or the main island of Japan, and the eastern border of the Kweichow Plateau to the Riukiu Arc.

Inside this inner Neocathaysian geanticline several basins occur. On the western side of the Great Khingan lies the vast basin of Mongolia filled with Jurassic to late Tertiary deposits. This depressed area in the Mongolian Plateau corresponds to the Okhotsk Sea on the western side of the Kurile Arc. Another basin, namely, the Shensi Basin, was formed later than Triassic times behind the Shansi geanticline and corresponds to the Sea of Japan on the western side of the Honshiu Arc. The third basin is the Red Basin of Szechuan located behind the Gorge Mountains of the Yangtze and the Kweichow Plateau, and duplicates the history of the Shensi Basin. It corresponds to the

Yellow Sea or Tunghai on the western side of the Riukiu Arc. All these inland basins would have been a continuous geosyncline if they were not separated by the east-west zones.

Such an extraordinary relation between the sinking areas and rising land barriers in eastern Asia is an obvious demonstration of the interference of the east-west zones with the Cathaysian geosynclines and geanticlines. If the east-west zones are features peculiar to eastern Asia, then they could be merely regarded as regional characteristics resulting from local tectonic causes. The fact, however, that they always occur in definite latitudes across parts of several other continents, unless they are overshadowed by other tectonic systems, is something which cannot be taken as accidental coincidence. It requires an explanation — an explanation which must touch upon, to say the least, the behaviour of our planet as a whole.

In his tidal analysis Sir George Darwin first deduced theoretical mountain ranges parallel to the equator. This illustrious master of earth-science further refers to the effect of rotation of the earth if it be inconsistent with its exact shape. Such an effect would be similar to the tidal force in raising the mountains parallel to the equator under certain conditions prevailing in the interior of the earth. From the geological point of view we are only concerned with the development of the surface features. If a satisfactory explanation could be found with regard to the genesis of the features within the range of our direct observation, the interior condition of the earth would have to be more or less determined by such an explanation. It would be well to leave the interior conditions for the geophysicist to handle. For the time being, we are not particularly anxious to rely either on the tidal force or the rotational force to account for our east-west zones. The important point to be emphasized is that the force required must be such as to be a function of zonal harmonics, usually written in the form :

$$P(\cos \theta),$$

where P is a function of zonal harmonics, and θ may vary between 0 and π.

If the force equation is of *n*th order, then there will be *n* zeros symmetrically arranged on either side of the equator. The terrestrial poles in this case are also the mathematical poles. The number of east-west zones actually observed may yet prove to be of some help in the final solution of the problem.

The question must now be faced: why the east-west zones, so powerful in character and probably planetary in origin, are not developed all round the surface of the earth? Eastern Asia again provides us with evidence for answering this question. We have devoted a whole chapter to describing the geotectonic shear-forms developed in China. Large sheets of continental material have been horizontally sheared southward. Some of those sheared sheets are actually involved in, or intruded into, the east-west zones. The Huaiyin-Huaiyang system, for instance, is developed on the site, and at the expense of, the eastern Tsinling, rendering that part of the Tsinling zone into an arc by a forcible bending and lateral tear. Nearly all the large tear-faults, *e.g.*, the Chushui* fault, are restricted to the western part of the arc, that is, in the neighbourhood of the main Tsinling Range, where the effect of tear is naturally the strongest. At the same time, the frontal arc of the system is somewhat distorted. Instead of facing due south as in normal cases, here the whole system is slightly turned to the west of south, as if it has been caught on its western side by the obstinate zone of the middle Tsinling.

Similarly, the asymmetrical arrangement of the Hsiaosiang system can be explained on the ground that it encounters a more powerful resistance from the middle Nanling on its western than on its eastern side. The system is therefore somewhat twisted to the west of south. In this case, the pre-existing system out of which it is developed may have exercised some influence in giving the affected region pre-disposed lines of weakness, such as Tupangling. Such lines of weakness would naturally be incorporated, with some modification, in the later system.

* About lat. 30° 40′—31° 40′ N., long. 114° 45′ E.

From the ξ system developed in eastern China, and especially south-eastern China, we have already concluded that such a shear-form indicates either a horizontal movement on the part of the Pacific floor towards the north or a horizontal movement on the part of the land towards the south. We were unable to decide the case *per se*. Now we see that all those regions which are involved in the ϵ type of shear-form sheared southward. It is thus safe to conclude that it was the continental mass that moved southward; and in consequence the Cathaysian axes arose. In the Nanking area the reflex ϵ is developed out of the Cathaysian base. The two systems are so superimposed that they point to one and the same kind of movement in the region of the eastern Tsinling, namely, the continued development of the Huaiyin-Huaiyang system by shifting the surface layers of the continental mass southward.

One of the most spectacular tectonic systems exemplifying the ϵ type of shear-form is the Irkutsk system. The main features of this system were already clearly recognized by E. Suess, and were more recently typified by E. Argand. The importance of the reflex arcs, however, was not duly emphasized. The "Irkutsk Amphitheatre," embracing the Sayan Ranges on the west and the Transbaikalian on the east, forms the frontal arc of the system. The Sayan Ranges, as they stretch to the north-west, gradually turn to the west and then south-west, joining the Sailiugem with a crescentic basin, the Uriankhai Basin, on its southern side. This is the western reflex arc of the system. The Transbaikalian axes likewise bend round the Vitim Plateau with a convex front facing the north. Here lies the eastern reflex arc. The main frontal arc is thrust into the Tannu-Kentai zone, which is thereby rendered arcuate and broken in its middle portion. The backbone of the system is founded in the narrow horst of Primorski Khrebet, a meridional ridge in the middle of the Irkutsk Basin. It consists of Archæan amphibole-gneiss with a strict north-south strike. This system had evidently already originated in Pre-Cambrian times. Recurrent movements in later ages along similar lines have much exaggerated its V-shape, and have induced more Sayan and Transbaikalian folds stretching far to the north-west and north-east respectively. The presence of the Anabar massif in northern Siberia may have been connected with the development of the backbone in its early stage. The Irkutsk system again indicates a southerly movement of that part of Siberia which it covers.

The largest example of the ε type of shear-form is the grand Eurasian system. The frontal arc of this system is of composite nature. A number of geosynclines and geanticlines are involved in it. They extend from north-western Europe, where they are known as the Hercynian Chain of Palæozoic times, to the Tienshan and Altai Ranges of central Asia. The Alpine area, a part of the Dinarides, the Carpathian, Caucasian, and Iranian Ranges appear to be all involved in the frontal arc. The Urals form the backbone of the Eurasian system. Although the complete history of these complex ranges is still ill-understood, it cannot be gainsaid that a system of mountains within the scope of the present Eurasian arc and the Urals was brought into existence by the Hercynian or Variscan movements. Later movements have partly rejuvenated, by uplifting, the old mountains which were incapable of further folding, and partly gave rise to new folds. The framework of the system remained, however, essentially the same.

At both ends of the frontal arc, the characteristic reflex arcs are present. The Tienshan and probably the Altai represent the eastern reflex arcs, with the Tarim and Tibetan massifs lying on their concave side. These ranges were folded in Upper Palæozoic times. Being incapable of further folding along the same axes, they were uplifted in mid-Tertiary times when subjected to compression. Similarly, the Hercynian Chain appears to represent the western reflex arc, with its western end running into, and in some cases across, the Armorican zone of east-west trend. In southern Europe the effect of the Hercynian movement is still ill-understood; but the observed unconformity between the Permian and the underlying formations in parts of the Alps indicates that that orogenic zone was also to some extent affected by the Upper Palæozoic movement. It was, however, not until mid-Tertiary times that the present Alps were brought into existence. Thus we may compare the Swiss mass, south of the Helvetic sheet, with the Tibetan massif, in so far as their positions with reference to the Eurasian arc are concerned. We may further regard the Hercynian Chain as the northern reflex arc, and the Alps as the southern reflex arc, attached to the western part of the grand Eurasian system. The migration of orogenic site in Europe since Upper Palæozoic times simply means, from our point of view, the migration of a reflex arc in the Eurasian structure. Such a shifting of intensified orogenic movement from one reflex arc to another of homologous nature does not alter the essential arrangement of the whole system.

The Eurasian continent within the framework of the ε system must have periodically moved southward against western Europe on the one hand, and central and eastern Asia on the other. Whether the frontal part of the area thrust under or thrust over the foreland is immaterial, that being dependent on regional or local circumstances. In the Huaiyang arc of eastern China, we have seen that the northern part of the arc is overthrust to the south, but the southern part of it is sometimes underthrust to the south. Obsessed by the impressive sight of extensive thrust sheets in the Alps and Himalaya, geologists are led to conclude that in Asia the mid-Tertiary movement came from the north and in Europe from the south. By fixing our attention on one aspect of the truth we are apt to forget the important fact that overthrust is necessarily accompanied by underthrust in the opposite direction; for thrusting is only an extreme case of horizontal shear.

This brings us to another point which is not always fully explored by geologists, namely, the differential movement between the upper and lower layers of the continental mass as a result of extensive horizontal shear. By assuming that the major horizontal movement necessarily involves the whole thickness of the continental mass, fantastic geographical reconstruction often becomes inevitable. The more the sheet-folds in the mountain-locked area are straightened out, the more is space demanded of the continent to accommodate the deposits in their restored original form. A continued pursuit along those lines will soon land us in a position where we shall find our earth much too small to accommodate all of the restored continents. Even allowing a more dilated existence of our planet in the past, we shall probably still find a resulting misfit.

Speculative discussion of this kind will, however, lead us nowhere. Let us return to the ϵ system of Eurasia. Two facts stand out prominently in connection with this system. Firstly, the ϵ type of structure was already in existence in Upper Palæozoic times, if not earlier. Secondly, within this system there is no sign of the east-west zone. The first fact has an important bearing on the question of migration of the poles, and the second indicates that the east-west zones can only develop in places where no extensive regional shear has taken place.

In western Europe, as in eastern Asia, where the east-west zones are present we find that the shear-forms are only developed within the framework of the east-west zones. The northernmost of these is the British system of the ϵ type. The backbone of this system is the "backbone of England," the Pennine Range. Painstaking work along this line of disturbance by numerous British geologists, particularly that of Jones, Hickling, Fearnsides, and Wickham King, enables us to understand that the whole range consists of a series of domes running nearly north-south. King's model* of the South Staffordshire coalfield well illustrates the stress condition in the southernmost part of the Pennines as well as in both wings of the frontal arc. The frontal arc of the British system is of composite nature, and is buried by younger deposits as it sweeps towards the east. The western part of the arc abuts against the Welsh massif, on the border of which disturbance of a most violent type is often observed. Starting from Flintshire, on the west, where the main arc tends to open out to form a reflex arc, the irregular arcuate front of the system may be traced along the border of Shropshire down to Burford in Oxfordshire,

* This model is now exhibited in the Lapworth Museum of Birmingham University.

where the apex probably lies. The Malvern Hills appear to represent the backbone of a local reflex ϵ. East of Burford, the frontal arc sweeps round under the Mesozoic formations, following the Melton Mowbray and Market Harborough axes, and is probably further continued into the area of the Wash, according to Cox. It is of interest to note that here again the arc tends to open out, suggesting the presence of a reflex arc.

The Gallian system of France is also of the ϵ type. In western France, particularly in the Brittany area, the western part of the frontal arc is composed of a series of folds running north-west, and tends to open out towards that direction. The extreme north-western part of the arcuate front of the system becomes almost amalgamated, in northern Brittany, with the Armorican zone of east-west trend. In south-western Germany and eastern France the north-east directrices predominate. These north-east and north-west directrices become confluent in the "massif central," where violent igneous activity characterizes the apex of the system. The backbone of the system ought to appear in the neighbourhood of Paris as a meridional ridge. But it does not. One of the two reasons stated below must account for the fact. First, the backbone may have actually existed, either in the form of a broad and elongated dome or of a sharply folded meridional zone, at the time when the system came into existence, but has since broken down and become covered by the deposits in the Parisian Basin. Secondly, at the time when the system was in the process of formation, the surface layer involved was so plastic that it failed to raise the backbone. In the latter case, there ought to exist a series of curved folds on both sides of the median line, namely, a line joining Paris and the Central Plateau, opening out towards the north-west on its western side and towards the north-east on the eastern side of it. Inquiry along these lines will probably throw some light upon the problem.

On the southern side of the Pyrenean zone, we find the Iberian system, again of the ϵ type. The western part of the frontal arc is represented by the Celtiberian Ranges, which, as they stretch towards the north-west, are bent backward to form the reflex arc, with the Madrid Plain spreading out on the south. In this plain rises a meridional hill-range largely composed of Cretaceous strata and stretching behind the reflex arc. This hill-range and the reflex arc may therefore be considered as a reflex ϵ. The eastern part of the frontal arc is broken down, and partially sunk into the Mediterranean. Thanks to the Balearic Islands, the essential character of the eastern wing of the frontal arc can still be traced from the north of Cape de la Nao to Minorca. In the latter island, the reflex nature of the arc is plainly exhibited. The backbone of the system runs along the eastern coast of Spain, and is likewise partially broken down. The whole system is not only shattered, but is twisted to the west of south.

Another grand system of shear-form of the ϵ type is found in the North American continent. The Palæocordilleran Ranges form the western wing of the frontal arc, and the Appalachian Mountains the eastern wing. The backbone of this system is not so sharply developed as in the Eurasian system. Nevertheless, its existence in the form of a broad arch is a matter beyond doubt. After a searching analysis of the structure of North America, Arthur Keith duly emphasizes this broad belt of land-mass running meridionally in the interior of North America, and actually calls it the "backbone of North America." The palæogeographic maps of Schuchert and Grabau also lucidly demonstrate this feature so far as the Palæozoic Era is concerned. Whether the high mountains in Grant Land and Ellesmere Land have anything to do with the backbone of this system is still an open question. Other tectonic systems are superimposed on the western wing of the frontal arc. This complication became much more exaggerated as a consequence of late Mesozoic movements. Reasons will be given later as to why such a complication should appear along the western border of the North American continent. Meanwhile, we note that the east-west zones are only developed outside of this enormous sheared sheet of continental material, precisely in the same way as happened in Eurasia.

Thus the ϵ type of shear-form developed in Asia, Europe and North America, all agree in showing southerly shearing movements which have affected large and small areas all over these continents. Wherever the shearing movement is "dominant," the east-west zones become "recessive."

Let us now turn our attention to the Southern Hemisphere. Two shear-forms of the ϵ type are developed side by side in South Africa, to the north of the Cape zone. Both of them are partially broken down. The remaining parts are, however, sufficiently characteristic as to leave little doubt about their existence. The eastern system is much the larger in size. It appears to have double frontal arcs concentrically arranged. The northern border of the northern, or outer, arc is roughly defined by the River Zambezi, and that of the inner, or southern, arc by the River Limpopo. The western wing of the outer frontal arc appears to extend as far as Lake Ngami, but the eastern wing is partially cut off by large faults in Portuguese East Africa and probably along the coast. The western wing of the inner frontal arc is represented by a swell of ancient rocks, including the Transvaal and Ventersdorp systems, the Witwatersrand and Black Reef Series, and the Campbell Rand Dolomite. These elevated rock-masses form an elongated belt extending south-west between the Kalahari Basin on the north-west and the Karroo Basin on the south-east until it reaches the neighbourhood of Prieska, where it is syntectically connected with the frontal arc of the western system.

The eastern part of the frontal arc dives, at first, into the lowland of Portuguese East Africa, and then becomes drowned by the Indian Ocean. The backbone of the system is located in Swaziland and Zululand, being obliquely cut off by the Indian Ocean. Further south, the main axis of the backbone seems to be somewhat distorted. But the presence of strips of old granite, gneisses and Rhodesian schists indicates that it extends as far south as Pondoland.

The western South African system of the ϵ type is developed in the western part of Cape Province, Bushman Land, Gordonia, and the lower reach of the Great Fish

River. The frontal arc of the system starts, on the east, from the Doornberg with highly folded Primitive and Nama strata striking north-west. From Upington westward, the main axis of the arc turns round towards the west, past the Kara Mountains, and then enters the valley of the Great Fish River, where the general strike of the strata turns towards the south-west. Further west, the frontal arc is cut off by the Atlantic coast. The backbone of the system runs more or less along the Atlantic coast, and is composed of a group of folds stretching from the neighbourhood of Cape Town to the north.

These two South African systems of the ϵ type join each other in the longitude of Prieska as already noted. Each of them indicates an independent shearing movement to the north. The compressed front of the two sheared regions would tend to elongate laterally. Along the line where the two fronts laterally collide, compression in the east-west direction would result. This effect of lateral expansion, due to the general north-south compression experienced by the frontal arcs, is shown in two ways. (1) Between the two frontal arcs of the two ϵ shear-forms we find a series of meridional hills, the Langeberg, with distinctly north-south axes, lying at the junction of the forelands of the two arcs. (2) The backbones of the two systems do not point due north, but the western one to the west of north and the eastern one to the east of north, neither of them being parallel with the Langeberg. Such a peculiar arrangement can be readily explained on the ground that the two systems laterally pushed against each other towards their front.

In south-west Africa, nearly the whole region is dominated by structural axes running north-east. Evidently they belong to the ξ type. The presence of these parallel folds and thrusts striking north-east and running somewhat obliquely to the western coast of the continent, indicates a horizontal movement on the part of the eastern land-mass against the Atlantic area. As a matter of fact, such a shearing movement is shown by the eastern ϵ structure, with its outer frontal arc thrust into Southern Rhodesia, as already discussed. Thus evidence derived from two independent sources supports the same view. It appears therefore safe to conclude that South Africa as a whole sheared northward. The region of maximum shear lies in the eastern part of the land.

In the low latitudes of the Southern Hemisphere, we find further tectonic types which throw light upon another component of continental movement. One of these is the Amazon system of the ϵ type. The main frontal arc embodies the Coro Mountains and the Northern Andes, which in the northern part of South America describe a bold arc. Instead of facing north or south, it faces the Pacific on the west. The northern part of the arc ends in the Lesser Antilles and surrounds the Caribbean Sea, so forming a reflex arc. The southern end of it stretches into Bolivia, again with a tendency to bend backward. Important investigations made by J. A. Douglas along the southern part of the Peruvian coast enable us to understand that a sharp change of structural lines takes place in the Mollendo-Arica area, and that the extra-Andean zone possibly dates back from Archæan times. The backbone of the system should more or less coincide with the Amazon Valley. Instead of a zone of upheaval, we find, however, a belt of subsided land. This does not mean that the backbone is absent; for, according to H. Keidel, the general strike of the strata on both sides of the Amazon Valley is east-west. The region has undoubtedly gone through a complicated history of which little is yet known.

Another tectonic type or types occurs in Western Australia. In north-western Australia, particularly in the Kimberley area, the prevailing strike of the strata is north-east. But in south-western Australia the country is largely occupied by granite, with numerous dykes and mineral lodes running generally in a north-west or north-north-west direction. We do not yet know the origin of the dykes and veins. If they prove to be compressional instead of tensional features, then it is not unlikely that they, together with the Kimberley folds, form the frontal arc of an ϵ system whose backbone coincides with the east-west zone already referred to. As far as our present knowledge goes, no definite conclusion can, however, be arrived at.

A third kind of continental movement is deduced from a shear-form belonging to the η type of structure. We found typical examples in the Wuling system of south-western China, and in the high ranges east of the Himalaya continued down to Burma and the Sunda Islands. The same type of structure appears to have developed in Australasia, including New Guinea. The incurved arrangement of tectonic axes characteristic of the anterior part of the η type is exhibited by more than one concentric arc of islands surrounding the Banda Sea. The inner arc consists of a group of small islands, including Ombay, Wetter, Serwati, and a number of others. The outer arc starts from Buru, passing eastward along Ceram, then southward along the Key Islands and Babber, and finally south-westward through the Tennibers. These arcs are related to the Flore Islands to the west in precisely the same fashion as the anterior part of the Wuling system is to the eastern end of the middle Nanling zone, and the *Faisceau du Mékong* to the eastern Himalaya. The Isle of Timor may be compared with the Yuechengling in the Wuling system, and with the Patkoi Mountain on the south-eastern side of the terminal part of the Himalaya. The grandeur of the system may be realized when we turn our attention to the axes of New Guinea, the coastal folds of Queensland, and the Australasian and Micronesian festoons of Gregory.

One more example of the η system will suffice to illustrate its importance. The northern Cordilleras of North America are highly incurved around the Gulf of Alaska, with the Aleutian Islands stretching towards the west, suggesting a similarity to the Flore Islands in their relation to the Banda arcs. In Alaska itself we find an arcuate arrangement of folded mountains such as the Kenai, Chugach, St. Elias, Alaska, Mentasta and Nuzotin Ranges. This arc is succeeded farther north by more homologous arcs along the course of the Yukon and in the Endicott Range. Southward, elements belonging to this system reach British Columbia, where they become amalgamated with the Cordillera proper.

If our experimental evidence can be applied to these systems, we would infer that the regions affected by the η type of structure have undergone a twisting movement with the centre of the rotational shear located somewhere inside the anterior arcs. In fact the reflex arcs of the ϵ type of shear-form conform essentially with the η type. Such a twisting movement can only happen, and is bound to happen, when a layer of continental material fails to move uniformly along a rectilinear front. In passing, it may be noted that folds associated with shear-forms largely belong to the class of *plissement de couverture*.*

In this rapid survey of the more outstanding shear-forms all over the world we have purposely neglected the chronological aspect of the problem, which from the geological point of view is certainly of paramount importance. This is done partly for the reason of simplifying our discussion, and so to save space, and partly owing to the writer's ignorance of the chronological development of parts of the systems. In view of the fact that the component parts of the typical shear-forms developed in eastern Asia can all be correlated with reference to time, it should not be a matter of grave concern for our present purpose if the chronology of the shear-forms occurring in other areas, almost identical with the standard type, is not dealt with at length.

From the analysis of the various shear-forms we can arrive at a fairly simple conclusion regarding continental movements since, at any rate, late Palæozoic times. The Eurasian mass sheared southward as a whole and also in different sections. The southward shear in south-eastern Asia was accompanied by a differential westward movement, and in consequence produced a torque. The North American continent also sheared southward, again accompanied by a differential westward movement. The combined effect was to twist the continent clockwise. South Africa, however, sheared to the north, and the northern part of South America shifted to the west. Australia probably also

* Professor O. T. Jones, of Cambridge University, fittingly discusses the nature of shear-forms in terms of "skin-effect."

accomplished a clockwise twisting movement. Each of the twisting movements can be explained on the ground that the sheared layer of the continents encountered unequal lateral resistance, one side being met by some obstinate mass, while the other was relatively free. For this reason we may regard the twisting movement of Australia as due to a northerly shifting of the land-mass, which encountered a strong resistance on the north-east and was relatively free to move on the north-west. The result was necessarily a twist. Similarly, after breaking away from Greenland, North America was freer to move to the south in its eastern part than in its western. Hence the tendency to rotate clockwise.

Our conclusion derived from the shear-forms can therefore be further simplified. All tendencies to shearing movement on the continents are to be reduced to two components: the one towards the equator and the other towards the west. The latter is more pronounced in, if not restricted to, the low latitudes. This conclusion sounds strikingly Wegenerian; but the evidence, as we have seen, is derived from entirely different sources, which do not demand wild drifting of the continents or extensive migration of the poles.

Origin of Tectonic Movements and Marine Transgressions

Thus far our argument is straightforward. The whole logical structure will either have to stand or fall with the basic conception of tectonic types and their mechanism as we understand it. Let us now go a step further with the assumption that our interpretation of the tectonic types outside eastern Asia is not far wrong and that our deduction holds. There are not many sources of force which could produce the kind of movement arrived at in the course of our argument.

The harmonic zones upon which emphasis has been laid suggest that their origin is either due to tidal force or to changed rotation of the globe. Convincing geophysical arguments are decidedly against tidal force alone as an adequate cause of continental movements. Let us then turn to rotational force. If the earth has been rotating at a constant speed since the early time of its existence, it would have established long ago the required ellipticity; and the resultant of the centrifugal force and gravity would have no horizontal component to satisfy our requirement. If, on the other hand, a change of speed occurred periodically, a surface re-adjustment would necessarily follow unless the interior of the earth is utterly devoid of strength. In other words, if the surface layer of the earth is more readily deformable than its interior, then, under an increased speed of rotation, a horizontal component of the centrifugal force, which is zero at the poles and equator and a maximum in the latitude of about 45°, would tend to urge the movement of masses towards the equator so as to produce a new form of mass-distribution appropriate to the increased rotational speed.

Our argument should not, however, be formulated in this way. It is manifestly unsound to found any theory on the basis of uncertain conditions of the interior of the earth. We must proceed from the surface, and find a satisfactory reason to account for the two components of continental movement and the development of the east-west zones. The implied conditions of the interior must be determined accordingly unless they flatly contradict unquestioned geophysical evidence.

At this stage it may be of interest to mention an experiment in which the various types of shear-form that we have considered are produced by means of the rotational force. A hollow steel hemisphere is attached to the spindle of a motor capable of rotating at a speed varying from 600 to 2,800 revolutions per minute. The hemisphere is polished inside, and lined with a thin layer of heavy paraffin on which are spread several coats of cellulose solution mixed with red and then white lead powders. The cellulose-lead mixture does not cover the entire surface of the hemisphere, but is made to assume the outline and orientation of the Eurasian or North American continent; that is to say, the width of this layer of material narrows towards the rim of the hemisphere in the radial direction. When this composite coat is

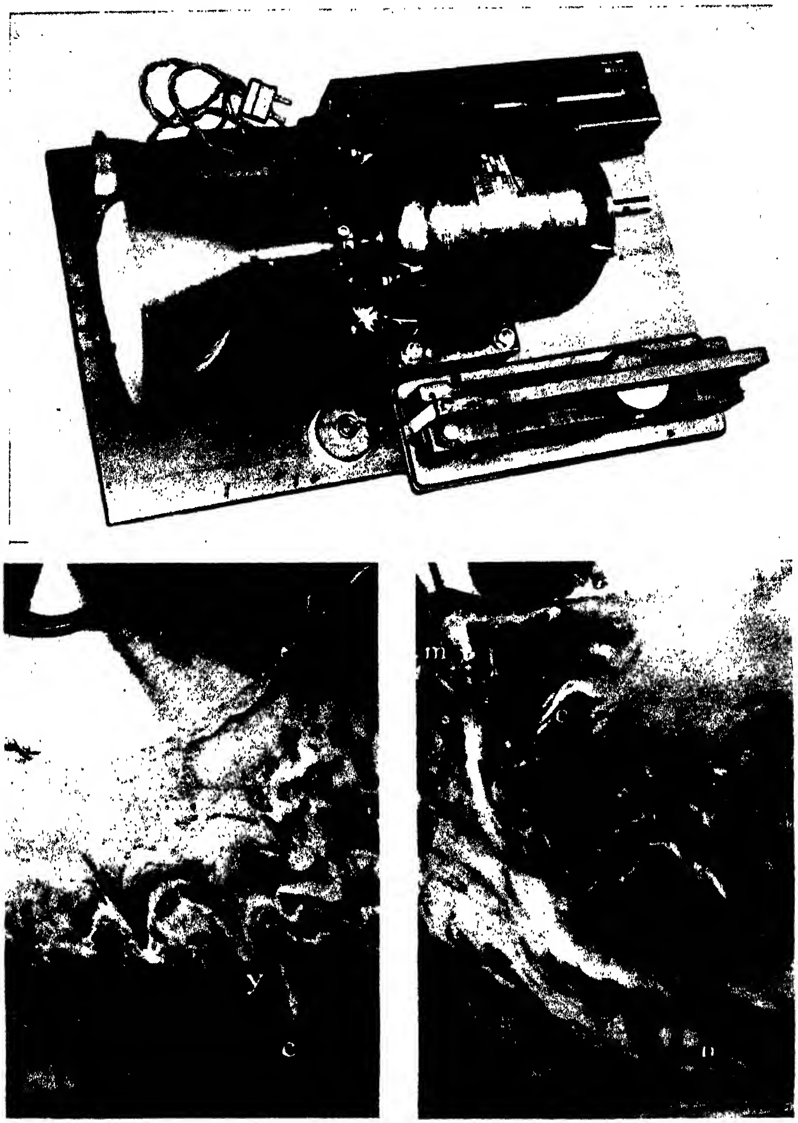

FIG. 77. An experiment with a layer of softened cellulose-lead mixture attached to the concave side of a rotating hollow hemisphere. *Above:* A D.C. motor with the hemisphere attached to it. *Below:* Strain-figures produced in the cellulose-lead layer after rotation. a, b, c, x, y, ϵ type of folds; e, ξ type; m, n, η type.

softened by butyl acetate so as to render it into a suitably elasto-plastic condition, the hemisphere is set to rotate. After rotating for a few minutes, that part of the cellulose coat which, for purposes of comparison with our continents, we shall describe as "frontal" (see *Fig.* 78) becomes intensely folded after the η type, not unlike the general pattern of the Pacific coast ranges of North America or the Cordilleras of south-eastern Asia. The rear part of the cellulose coat is folded parallel to its margin. The folds are, however,

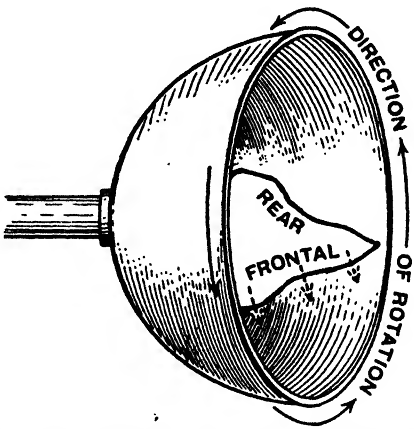

FIG. 78. Diagram illustrating the experiment with a rotating hemisphere.

Note that the part which we have described as "*frontal*" actually formed the *rear* during rotation. As the hemisphere rotates, the cellulose coat tends to lag, so that from the point of view of an observer stationed on the moving hemisphere the rear or lagging margin would *appear* to be the "frontal" one.

less compressed, and do not conform with the η type of structure in arrangement, but are rather suggestive of the Cathaysian or Appalachian type.

When the cellulose coat is more or less uniform in thickness, and when a film of oil is applied on its sub-surface so that it can easily slip on the surface of the hemisphere uniformly, then, after rotation, we find numerous folded zones all parallel with the rim. Apparently these correspond to the east-west zones occurring in nature. They differ, of course, in number and in latitudinal position. If, however, the coat is not uniform in thickness, or if parts of it are comparatively loosely attached to the hemispherical surface, then shear-forms usually of the ϵ type are produced as a result of the heavier or loosely attached parts (less viscous parts) gliding away from the centre of the rotating hemisphere.

The object of this experiment should be clearly understood. We have no right, of course, to claim that our continents are something of the nature of a mixture of cellulose and lead. That is not assumed for the purposes of our present demonstration. What does seem to commend itself to our notice in connection with this experiment is the fact that shear-forms which actually occur in various parts of the continents do agree in type and orientation with the miniature shear-forms produced in a certain kind of material spread on a spherical surface when it is set to rotate. In short, we are here only concerned with the morphology of strain-figures produced in a thin sheet of elasto-plastic material when it is exposed to a field of force due to rotation, and when it is attached to a spherical surface. The method of photo-elasticity, which is frequently used by physicists and engineers, and which has proved to be so helpful in determining strain conditions in a plane, is rendering us a similar service, though, of course, with a much greater precision.

Reverting to our main argument, we must now proceed to examine how far the major surface strain-figures of the earth would agree as regards their distribution with those produced by the operation of rotational force. As noted above, the horizontal component of the centrifugal force is nil at the poles and along the equator. It varies in magnitude from latitude to latitude for a given mass; but it is always directed towards the equator. Those continental masses which extend into high latitudes would tend to stick to their floors in those parts which are in high latitudes, but would tend to move more vigorously in the middle latitudes where the horizontal component attains its maximum. We would therefore expect fractures to develop in high latitudes in those continental masses which extend so far north or south. This is what actually happened to that extraordinary mosaic of land-masses in Arctic America and, to a certain visible extent, along the Arctic coast of Siberia.

Before breaking away from Greenland, the triangular mass of the North American continent hung, as it were, to the Arctic at its north-western as well as its north-eastern corner; but by cutting off its north-eastern connection with Greenland, the equator-ward movement of the continent was held back only by the Alaskan region. Consequently, the continent began to twist when it was urged by the horizontal force.

In the low latitudes, the continental masses, when present, would be subjected to compression from the north and south, if such masses extend into the Northern as well as Southern Hemispheres. The result of this north-south compression must therefore depend on the distribution of the land-mass and its mechanical properties. When the mass has no connection with those in high latitudes, and when it encounters unequal resistance on the equatorial side, then, instead of being pushed uniformly towards the equator, it also tends to twist. The direction of the twisting movement depends on the position of the supporting mass in relation to the mass on the move. The triangular mass of Australia, including the floor of the shallow Arafura Sea, is hinged upon its northern apex against the equatorial mass of New Guinea. Judging from the present configuration of the continent, which in past ages may have even extended farther west, we see that the hinge is not located on a line of longitudinal bilateral symmetry, but on the north-eastern corner of the mass. When the Australian mass was urged as a whole towards the equator it could not fail to rotate clockwise in those circumstances.

Where large continental masses are involved, the effect of the north-south compression may be so strong that they will expand in the east-west direction in accordance with Poisson's rule. Such an east-west expansion may produce north-south fractures depending on the mechanical nature of the strata. This may account for the origin of the African Rifts, the founding of the Laccadive and Maldive Islands, and the Rift Valley of South Australia. Indeed, the breaking down of Gondwanaland, or at least Lemuria, may be traced to the same origin.

So much for the equator-ward component. If the continental mass, the sial, is not rigidly attached to the subcrust of the earth, we might expect that parts of the continental layers would slip off when the substratum is not strong enough, or not viscous enough, to transmit the increased rotational speed. In this way the fragmentation of the Caledonian Chain, the widening of the Atlantic and the rising of the Cordilleras may be accounted for. The reason that the Americas more readily slipped off may be connected with the inherent chemical nature of the lower part of the sial in this region. If it is more richly alkaline, it may possess a lower viscosity as compared with the calc-alkaline base. Therefore the supercrust of the American continents would be apt to be left behind when the rotational speed of the earth rose to a maximum. However, in view of the conflicting arguments that are still raging regarding the very existence of petrographical provinces, we cannot attach, for the time being, too much importance to this line of thought.

Since the linear velocity is highest in the equatorial region, a variation in rotational speed would give rise to a maximum variation in linear velocity in the equatorial region on the surface of the globe. Thus we see why the northern part of South America with the Amazon system of ϵ type pointing to the west, north-western Africa with the Saharan Atlas forming a ξ type of structure, south-eastern Asia with the characteristic η type of structure, and Australia with the arrangement of major structural directrices on its western part conforming with that of the ϵ type, all show a more pronounced tendency to move westward than the masses lying farther north and south. Also, the linear speed is directly proportional to the distance between the axis of the earth and a given point on its surface. In a given latitude, the higher the rock-masses are uplifted, the greater will be the effect. Similar variation in intensity with reference to latitude and altitude is to be ascribed to the horizontal component of the centrifugal force.

As a whole, then, the surface strain of the earth can be explained by an adequate increase of rotational speed. Have we any reason to assume an alteration of the earth's rotational speed? The tidal force is ready at our service. But in its feebleness, the tidal force tends to retard the rotation, and acts only in that sense. There is, however, another source of energy, neither chemical nor radio-active, but that born with the earth. Suppose the whole mass of the earth undergoes a process of condensation in the course of time, the rule of conservation of angular momentum will compel it to rotate faster.

Condensation of mass can, however, be brought about in a number of different ways. We will name a few for our choice. It has been the contention of a certain school of thinkers that segmentary foundering of the oceanic floor is to be regarded as the primary cause for orogenesis. If it is true, we should find that regression of epicontinental water takes place simultaneously with all kinds of tectonic movement, and that the uplifting of the mountain ranges bordering the oceans should precede the development of shear-forms and other features in the interior of the continents; whereas geological evidence seems to show that in the high mountains of the present day folding generally has preceded uplifting. As regards the inferred relation between tectonic movements and the movements of the marine water the evidence in some cases is not clear and in some cases apparently antithetic. Moreover, it is difficult to conceive that "wedges" or sectors of the shell of the earth could sink so uniformly that no appreciable displacement of the poles would result therefrom. Apart from the formidable geophysical objection against any extensive migration of the terrestrial poles, admirably presented by H. Jeffreys, we have so far failed to find any conclusive geological evidence that proves pole-migration. If the arguments which the writer has endeavoured to set forth be admitted, the dominant structural features in the continents that were generated in different geological times would be obviously against the alteration of the earth's axis to any appreciable extent; for in their general arrangement they bear a definite relationship to the present axis of the earth irrespective of the ages in which each set of them was brought about.

Another conceivable method of bringing about the required condensation of mass might be attributed to a deep-seated gravitational differentiation taking place on an extensive scale in the interior of the earth. The fusion phase of Joly's thermal cycle might help the process in a way hitherto neglected. If the basaltic substratum and its underlying peridotite or dunite zone were rendered into a fluid or semi-fluid state by the accumulated radio-active heat, the heavier elements in the earth's shell would be bound to sink; and if the effect due to the sinking of the heavier material exceeded that due to the slight expansion arising from fusion, there would be a resultant condensation of mass.

A third method refers to the time-honoured assumption of secular contraction. The theory of the "dried apple" has long proved to be untenable. Extensive horizontal movements demonstrated in various parts of the world have dealt this old conception a fatal blow. If the orthodox view is to be revived, it must adapt itself to the new evidence.

The first method is disposed of. The choice between the second and the third cannot be made on the evidence of the movement of the land. Each of these is, however, connected, in a delicate way, with the movement of marine water. If the earth actually expanded, due to the fusion of the basaltoid substratum, a general regression of marine water would take place before each episode of tectonic movement. If, on the other hand, the earth contracts before the orogenic movement, we should find a general transgression of marine water taking place prior to the movement.

Here, we have raised a vast and complicated problem, involving the whole question of marine transgressions in the past and their chronological relation to tectonic movements. With the limited space at our disposal we can only touch upon the problem in its broadest aspects. Serious complications arise from the development of geosynclines, faulted troughs, and extensive basins on the continents. Such depressed areas would be readily invaded by the sea without any general elevation of sea-level. Minor complications are still more numerous, such as the change of temperature, accumulation of inland ice, the distortion of the geoid due to the uplifting of high mountain masses, etc.

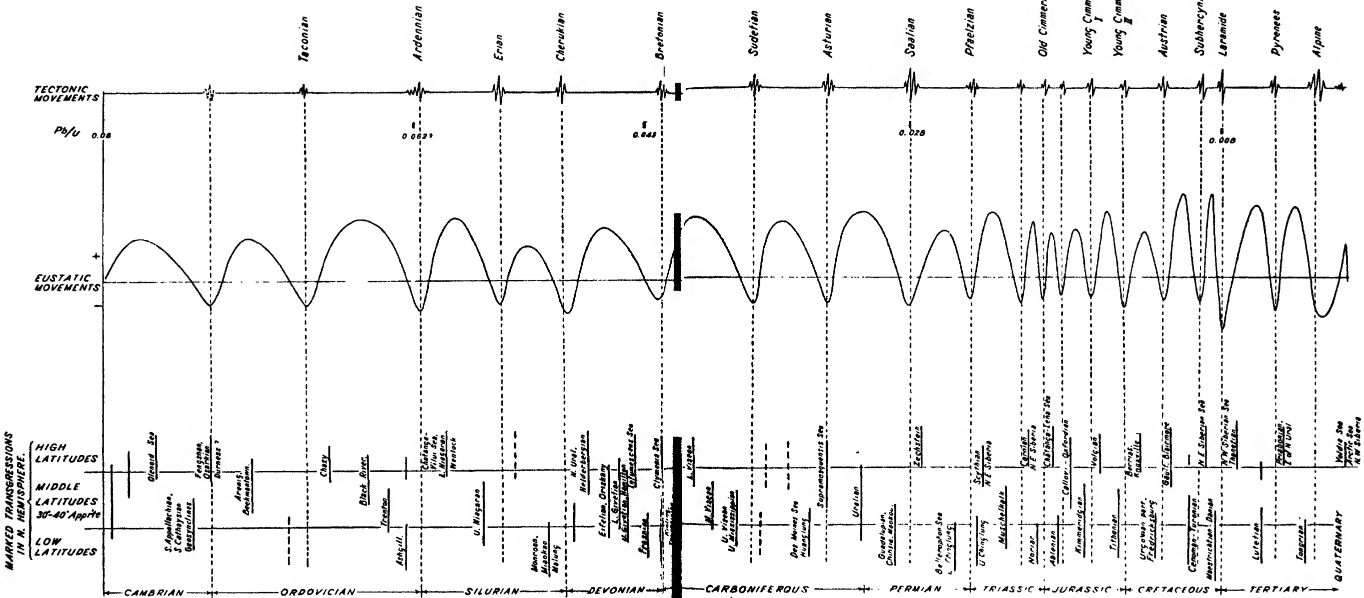

FIG. 79.—A graphic representation of important tectonic movements and extensive marine trangressions throughout geological times. The lead-uranium ratios (Pb/U) which mark the proportional lengths of time are based on Professor Arthur Holmes' estimates. Ordinates arbitrary.

Apart from all these complications there is one important effect which must be felt by ocean water if our theory holds. The ocean mass is devoid of strength. Under the

urge of increased rotational speed it would at once adopt a new shape of surface and become more oblate than before, while the lithosphere, on account of its strength, would keep its original form for some time. A general transgression in low latitudes would thus result. We must not, however, suppose that the ocean mass can move freely to such an extent as to produce a highly prolate surface in comparison with that of the lithosphere, for it is always under the powerful control of gravitational potential. This state of affairs continues until stresses accumulated in the continental masses become so strong that the substratum is no longer able to hold them in position, or the supercrust is unable to resist deformation and dislocation. Then a revolutionary orogenic movement breaks out. As a consequence of such an outburst, masses of continental material are forced to slide from east to west and from higher to lower latitudes, and are lifted, perhaps with the help of isostasy, from lower to higher altitude. At the same time, igneous materials are poured into or on the surface layer. The process of reluctant sliding coupled with a new distribution of mass would tend to slow down the rotational speed. The ocean surface would be rendered less oblate, and marine transgression in high latitudes is bound to follow.

In this way, the continents behave as automatic brakes which are set in operation when the rotational speed of the earth exceeds a certain limit. The corollary, in brief, is that general marine transgression takes place in low latitudes accompanied by general regression in high latitudes before orogenic movement breaks out, and that during or soon after the tectonic movement a general marine transgression occurs in high latitudes and general regression in low latitudes. In addition to this, we ought to have the effect of eustatic movement resulting from expansion or contraction of the lithosphere. Combining these effects, and neglecting the regional and minor complications, we should find a general regression occurring all over the continental area before an episode of orogenic movement, but to a lesser extent in low latitudes, if the lithosphere did actually expand. On the other hand, if it contracted, we should find a universal transgression before the movement of the land takes place, but to a greater extent in low latitudes. Conditions in high latitudes after an orogenic movement may be inferred accordingly.

The cardinal point of our argument rests on the assumption that tangential stresses can be stored up in rocks. Unfortunately, it is exceedingly difficult to measure or even detect such stresses by means of instruments. Professor W. S. Boulton has, however, noticed certain significant facts in connection with his investigation into the causes and circumstances which lead to colliery accidents, more especially through " crumps " and " rock-bursts." While pointing out the importance of rock-pressure due to depth in causing severe crumps underground, he calls attention to powerful tangential stress at work which cannot always be accounted for by mere depth, and further refers to two cases of special interest. Detailed investigation carried out in the Fuveau Basin of Provence led to the conclusion that the crumps which occurred in the lignite deposits of that field were " not caused by the weight of the overlying rocks in deep workings, but by great cumulative stress set up by the folding and thrusting of the strata containing the seams of lignite." Equally illuminating is the case of the Rhenish-Westphalian coal mines. There, " the liability of crumps . . . is greater when the measures are horizontal or nearly so than is the case when the measures dip at a considerable angle." It may also be added that the cumulative stress is so powerful that it sometimes brings about earthquakes when it is let loose through underground workings. Our assumption would thus seem to be justified.

We have not yet made our choice as to whether the earth has periodically expanded or continually contracted. Having exposed the major difficulties in treating of the subject of marine transgression, we may now risk an analysis with the object of extracting evidence which might help us to decide the issue. For this purpose, the major marine transgressions over the Northern Hemisphere since Cambrian time are plotted in the accompanying graphs with reference to latitudes and to the well-known epochs of orogenic movements. Incomplete and somewhat hazardous as the attempt is, a certain outstanding time-relation between the sweeping transgression and the revolutionary movements that ensued is revealed in a striking manner. The data thus assembled, when correlated with the " pulsations " of A. W. Grabau, who vigorously advocates universal transgression and regression for a given geological period, seem to favour the conclusion that it is the continued contraction of the earth that has caused the increase of its rotational speed. Such a contraction on the part of the lithosphere would also account for the apparent swelling of oceans in the course of geological time, as required by Schuchert, without borrowing water from the interior of the earth, which can only afford a limited supply, if at all, or from any extra-terrestrial sources.

It goes without saying that the law of synchronism of tectonic movement, as stoutly held by Hans Stille (see p. 328), is tacitly implied. Sweeping as Stille's contention appears to be, this law is steadily receiving support. As a significant example we may turn our attention to the valuable contribution made by R. G. S. Hudson in collaboration with J. S. Turner in clearing up part of the old problem of Hercynian movement in the British Isles. It has been recognized for a long time that important earth movements took place in Great Britain towards the end of the Palæozoic. Some would insist that the principal movement occurred in Permo-Carboniferous time, and some find evidence for a movement or movements in the Permian. Others advocate pre-Coal-Measure or inter-Coal-Measure tectonic disturbance. After summarizing his own observations in the Pennine Range and comparing them with the development in other parts of the country, Hudson came to the conclusion that the Hercynian movement in Britain can be divided into several phases, each of which corresponds to a phase of the Variscan movement in the European continent. Observations at the other end of the Eurasian continent, namely, in China, practically confirm every important episode of movement established in western Europe, however much the intensity of disturbance may differ from region to region. When we view the major transgressions and tectonic movements as a succession of connected events regulated by the alteration of the earth's rotational speed, we cannot but arrive at a conception already expounded by Stille. The period of quiet sedimentation in our scheme of interpretation corresponds to the evolutionary period of Stille, and the epoch of orogenic movement to his revolutionary period. It has been found in recent years that the rotational speed of the earth has actually accelerated and retarded periodically during historical times. Assyrian records of ancient eclipses show, for instance, that a day has been probably lengthened by some 1/200 of a second per century. Is such a retardation due to the feeble effect of the tidal brake or is it a sign of a commencing world revolution in the earth-crust?

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PART II

CHAPTER IX

PLEISTOCENE CLIMATE IN CHINA

THE problem of climatic changes in China since the latter part of Pliocene times is one of a fascinating and yet debatable nature. We have two sets of facts pointing in opposite directions. To do justice to these divergent facts, it is necessary to evaluate them independently, and allow them to weigh against each other for what they are really worth. We shall bear in mind that in such an attempt the evaluation of the chronological sequence of the facts is just as important as their climatic significance. Since the physiographical conditions now prevailing in northern China are widely different from those of southern China, it would be well to discuss the problem with reference separately to each of these regions. It seems also advisable to focus our attention on individual cases at the present stage of inquiry.

NORTHERN CHINA

In northern China we have a series of young deposits, called the Sanmen Series, resting upon eroded older rocks and forming local basins, such as the Nihowan in the Sangkanho Valley and Taiku in central Shansi. In the Nihowan Basin this series consists of lacustrine deposits, with heavy shells of *Lamprotula* and numerous vertebrate remains, including *Ursus, Hyæna, Felis, Rhinoceros* of the types *R. mercki* and *R. tichorhinus, Hipparion, Equus, Cervus, Bison, Siphneus,* and large *Elephas*. The lacustrine beds are underlain by a dark red clay with *Hipparion richthofeni,* belonging to the Paotuh Stage of Pontian or Lower Pliocene age. These deposits and the faunas they contain indicate a rather dry climate in early Pliocene times. Towards the latter part of that period, there was a marked increase of rainfall resulting in the development of the lacustrine deposits. Nothing, however, can be definitely said of the prevailing temperature as far as the faunal assemblage is concerned.

In the Taiku Beds, which are correlated with the Sanmen Series by G. B. Barbour, plant remains occur. These, according to R. W. Chaney, indicate a semi-arid and cool climate, as do their contemporaries elsewhere in the world. The exact correlation of the faunal and floral horizons in the two localities has not yet been effected with certainty. An element of doubt, therefore, still exists as to the tendency to a change of climate in China towards the end of Pliocene time.

The Sanmen Series of northern China is generally unconformably overlain by a Red Loam which in places contains coarse basal gravels or conglomerates. In the Taiku Basin, where Barbour describes a classical section of the young formations, the Red Loam cuts into the violet sands which form the middle part of the Taiku Beds, indicating an interval of erosion between the late Pliocene and the deposition of the Red Loam. The latter, together with its overlying Reddish Loam, is generally correlated with the Choukoutien Stage, which is of early Pleistocene age and which signals the appearance of Peking Man. Several observers agree in establishing the relative stratigraphical position of this red loamy material. The accounts given by Barbour and by Teilhard de Chardin and Young are particularly illuminating as to its climatic significance. The loessic nature of the material and the limy concretions that it frequently contains would certainly seem to point to deposition under arid conditions. From their observations in Central Shansi and elsewhere, Teilhard and Young conclude that the coloration of the red loams in northern China can neither be a quality inherited from the original material of which the loams are composed, nor a condition brought about by slow chemical processes long after their formation. They believe that at first some climatic conditions responsible for the chemical alteration of the loams must have prevailed, but that later the climate changed until the Malan

Loess was deposited. They are also of opinion that tropical regions would probably supply the conditions required.

Turning to the faunal aspect, reference may well be made to the unusually rich deposit in the fissures of Choukoutien, occurring in association with *Sinanthropus*. This fissure deposit has been assigned on reasonable grounds to the early part of the Choukoutien Stage. The fauna that it yields is a strange mixture. In an attempt to evaluate their climatic significance a few forms out of each group are here tabulated according to their accepted habitat :—*

A. Animals of tundral habit :

Rhinoceros tichorhinus Cuvier.
Gulo sp.
Arctomys robustus M.-Edwards.
Alticola sp.
Evotomys rofocanus Sundevall.

The two last-named rodents are probably equivalent to *Lemming*.

B. Sub-Arctic steppe forms :

Cuon alpinus Pallas.
Spermophilus mongolicus M.-Edwards.
Gerbillus meridianus Pallas.
Gerbillus roborowskii Büchner.
Ochotona (Lagomys) koslowi Büchner.
Ovis cf. *ammon* Linn.
Vulpes cf. *corsac* Linn.
Mustela siberica Pallas.
Meles leucurus Hodgson.
Canis (Nyctereutes) sinensis Schlosser.
Canis lupus variabilis Pei.
Microtus brantioides Young.
Microtus epiratticeps Young.
Pseudaxis grayi var. Zdansky.
Cervus (Euryceros) pachyosteus Young.
Spiroceros peii Young.

C. Animals which lived in temperate climates :

Rhinoceros cf. *mercki* Kaup.
Sus lydekkeri Zdansky.
Trogontherium cuvieri Fischer.
Hyæna sinensis Owen.
Hyæna ultima Matsumoto.
Lutra melina Pei.
Machairodus sp.
Macacus robustus Young.
Hystrix subcristata Swinhoe.
Bubalus teilhardi Young.

* The writer is indebted to Dr. C. C. Young and Mr. W. C. Pei for their assistance in arranging the table.

It will be seen that no conclusive evidence can be derived from this faunal assemblage as regards the prevailing temperature at the time when it lived. The occurrence of *Rhinoceros tichorhinus*, together with numerous other animals that usually subsist in cold regions, would seem to indicate a rather severe climate. And some of these are among the typical elements of the fauna of the Ice Age in Europe. They are, however, associated with buffaloes and other animals of a warm climate. In the case of the woolly rhinoceros (*Rhinoceros tichorhinus*), which is taken to be the characteristic tundral fossil of the Great Ice Age in Europe, we find its remains among the Sanmen fauna and in the later Pleistocene deposit near Harbin where it is associated with buffaloes and mammoths. The deposit near Harbin is evidently contemporaneous with the Malan Loess of northern China. In the Malan Loess fossil ostriches and buffaloes are also found. It is almost inconceivable that animals like the buffalo could endure a climate under which the mammoth existed; and yet their remains are found side by side.

Taking the Choukoutien fauna as a whole, Young concludes that in *Sinanthropus* times the climate was decidedly more humid and probably warmer than it is at the present day. Barbour, who has made important contributions to the problem of Pleistocene climate in northern China, holds a similar view. While admitting that the Red Loam is generally a transported material, Barbour states that it embodies, in different places, a certain amount of weathered soil formed *in situ*. Dark layers in the loam are believed to be due to the effect of insolation. The Red Loam, though still far from being lateritic, contains grains of manganese and iron and numerous calcareous concretions which are compared with the "kanker" occurring in India in association with true laterite. Finally, a deeply weathered surface underneath the loam, particularly in those places where igneous bodies are present, enables Barbour to confirm his view. Later in the stage there was a change, according to Barbour, towards drier and cooler conditions. On account of the extensive deposition of gravels and boulders in post-Red-Loam times, supposed to be due to torrential rain, the same author argues for another humid and warm period, corresponding to the Chingshui Stage of erosion. Then a drier and cooler period reigned again, as evidenced by the deposition of the Malan Loess—a buff-grey material undoubtedly of æolian origin. The last cycle was inaugurated by the Panchiao Stage of erosion, which has continued to operate until the present time.

It would thus seem that ever since late Pliocene times northern China went through periodic and perhaps progressive desiccation interrupted by pluvial intervals. No room would seem to be left on the chronological scale for any violent change of climate except for the time immediately before the deposition of the Red Loams (or soon after their deposition), if the significance of their coloration be rightly inferred by Teilhard de Chardin and Young. Barbour's deduction for gentle climatic fluctuations from cool and dry to warm and humid seems to be the most natural as far as the ascertained facts go.

On the other hand, certain obscure facts not in agreement with the foregoing interpretation are accumulating throughout the country. They demand an explanation in accordance with known geological processes and in harmony with the established climatological history of eastern Asia. In bringing out such obscure facts the writer wishes to emphasize certain neglected details. Before such details can be satisfactorily explained on the basis of the prevailing view, it would be harsh to rule out one possibility, namely, local glaciation.* Explanations in general terms can hardly be of any use in our discussion; for such an attempt is liable to prejudice the case in hand or even to cause confusion. Specific explanation must be sought for in each particular case.

From the accounts, not altogether reliable, given by travellers in northern China regarding the occurrence of erratics, James Geikie discussed a probable glaciation of that country in his treatise on the Great Ice Age. More than a decade ago large angular blocks of gneisses and schists were

* See Anon. (W. L.), "Quaternary Glaciations in Central China," *Nature*, Vol. CXLI, 1938, pp. 499-501.

found in the Tatung Basin, northern Shansi, in association with local debris in some of the valleys. The floor of that basin, some thirty to forty miles wide, is everywhere composed of Jurassic sandstones and conglomerates. It is separated by a broad valley from the high mountains on the west, whence the erratic blocks probably came. In association with the gneissic blocks occasionally occur planed and scratched subangular boulders with several sets of striæ that,

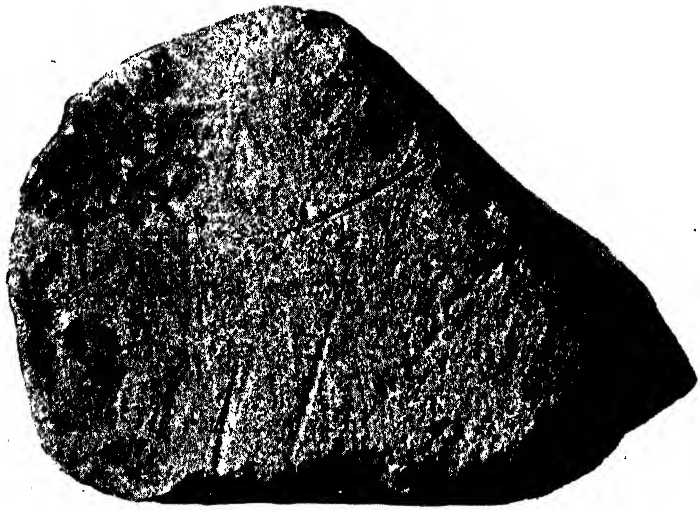

FIG. 80. A striated boulder of Jurassic sandstone found in the Tatung Basin, northern Shansi.

as far as the writer is able to judge, cannot be merely slickensides or scratches due to surface creep.

Large and small erratics have been noticed on the tops of a number of isolated hills among the Western Hills of Peking. On account of their position of occurrence, they are generally regarded as of Pontian or Lower Pliocene age. It must, however, be noted that apart from those cases in which stratigraphical and palæontological evidence is available, the Pliocene age of the boulders is by no means established.

One such erratic block, lying in the Plain of Peking at a point about 7 km. from the foot of the Western Hills, weighs some 15 tons. This block is composed of the Chiulungshan Conglomerate of Cretaceous age. We know, therefore, where it came from and that it has travelled for more than 7 km. across the plain. Judged from its jagged shape and solitary occurrence, no conceivable reason can be suggested for its transport by human agency. The question remains as to how it became removed from the bed-rock to such a distance, unless it were by ice.

In certain places on the eastern side of the Taihang Range similar strange blocks and occasionally scratched boulders, together with clays and sands, have been found in ancient stream courses or valleys that have been filled up. Large blocks of rocks of distant origin now and then occur on the tops of isolated hills. In one place in the western part of the Shaho district, northern Honan, a bed-rock of the Permian coal measures shows a distinctly striated surface which lies nearly horizontally. Close to that polished and grooved surface are found erratic boulders. The nature of the grooves and striæ are, however, not typical of those produced by moving ice. Moreover, the country is locally disturbed, rendering their explanation as slickensides even more probable. For the origin of the striated boulders of rather distant sources one might assume a landslip that had occurred under topographical conditions very different from those prevailing at the present day. Such an assumption seems to be admissible in the Shaho area.

In view of the arid conditions prevailing over northern China since late Sanmenian or late Pliocene times, and of the general absence of ice-sculptured features, one is not encouraged to look for traces of glaciation even if one disregards the highly oxidized state of the Red Loams. Nevertheless, in and near the high mountains, for instance, on the northern foot of the Huashan, about 1,700 m. high, deposits like boulder clay, together with gigantic blocks of the Huashan granite, are sent out far into the plain. Landslips in the wider sense of the term, coupled with deep weathering, might offer an adequate explanation for such cases without ice-action being invoked, were there no features in the higher part of the mountain that led one to suspect the existence of demolished cirques.

Still more suspicious are the features on the top of the Tapeishan in the northern part of the western Tsinling (about long. 107° 40′ E., lat. 33° 55′ N.). The top of this mountain reaches 3,300 m. above sea level, and 2,700 m. above the plain on the north. There exist five small tarns on the top of the mountain, each having a circumference of from 330 m. to 430 m. as measured on the surface of the water, and each has a U-shaped outlet. Under present climatic conditions the water in the tarns only begins to freeze on the surface during the winter season. These tarns are carved out of a granite. They cannot, therefore, be "sink-holes" such as often occur in limestone mountains. These features would seem to indicate the existence in recent times of mountain glaciers, perhaps of small size. But they do not throw much light on the main problem at issue; for the suspected erratics and boulder-clay-like deposits attain a much more extensive development in the low ground and are obviously older.

With these and other apparently conflicting records of evidence in view, the writer would venture to suggest, as a working hypothesis, that towards the close of the Sanmen Epoch a cool and dry climate reigned, as is advocated by Barbour. Then the temperature continued to fall; but humidity tended to increase, culminating in the development of a few local glaciers which were nourished by precipitation locally intensified through high altitude or otherwise. That such moist conditions are not geographically impossible is shown by the powerful stream erosion during the Chingshui Epoch which immediately followed. It is even suggested by K. L. Fong that the extensive formation of gravels in the Chingshui Stage may eventually turn out to be a physiographical expression of a possible glacio-fluviatile operation during the retreat of the ice.

Precipitation and evaporation were simultaneously going on. When the balance was in favour of precipitation there were dwarfed glaciers. These, in the dry region of northern

China, might have brought down from the higher ground quantities of re-worked loess on which they formed a thin cover in a few places; but when it was in favour of evaporation the dust-laden glaciers simply evaporated into the air, and the spreading of wind-blown dust would in general take the place of precipitation. Alternating processes like these can hardly allow much opportunity for the ephemeral ice tongues to bring down any quantity of disintegrated rocks except from the rugged peaks of the high mountains, or from places where the dust was swept off by blasts of strong wind; nor could they create, on the landscape, any strong impression that could endure the trial of time, except in those specially favoured places where they more or less persisted. If a glacier can "swim" in the moraine, as has been demonstrated by the Alpine glacialists, there seems no reason why it cannot swim in the loess.

This hypothetical attempt is merely intended to depict the kind of processes, not altogether inconceivable under the accepted climatic conditions, that are supposed to have prevailed in northern China towards the end of Red Loam times. The chances are that the erratic blocks and striated boulders already mentioned might be equivalent, in point of time, to the so-called fan conglomerate that underlies the Red Loam in the north. The correlation between the "fan conglomerate" and the Choukoutien fissure deposit with *Sinanthropus* remains is still an open question. In either of these time-correlations of the supposed glacial products no serious disturbance would result in the established stratigraphical sequence of the young deposits. With a short interlude of interglacial climate either in *Sinanthropus* time, or in the Chingshui Stage, or both, the succession of the physiographical stages and the appearance of a mixture of warm and cold faunal elements can be readily understood.

That this explanation seems to possess the advantage of causing the least conflict among the prevailing opinions is but a poor excuse, which, in itself, can hardly afford any justification for ardour on the part of its advocate. A picture painted on such a hazy background would be of little interest had there not appeared more details in other parts

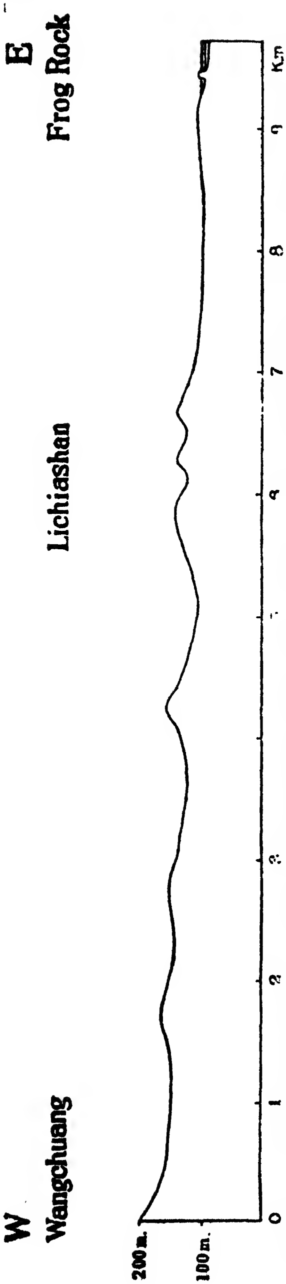

FIG. 81. Shape of the floor on which rests the clay-and-boulder deposit on the eastern side of the Lushan, between the mouth of the U-shaped valley, Wangchiapo, and the shore of the Poyang Lake. Note that the slope of the surface is almost negligible if the height and the horizontal distance are plotted on the same scale.

of the country worthy of serious consideration. These details, mainly stratigraphical in nature, are preserved in the Lower Yangtze Valley. We will now proceed to consider a number of typical cases, and allow the facts to speak for themselves. For this purpose it is obviously necessary to enter into some detail. Alternative explanations will be suggested in each case wherever possible.

THE YANGTZE VALLEY

In the neighbourhood of the northern part of the Lushan (lat. 29° 30′ N., long. 116° E.), a famous health resort in the Middle Yangtze Valley, a red, tough clay, with scattered large and small subangular boulders and cobbles, is widely developed beyond the foot of that block-mountain, which in its highest point reaches an altitude of 1,480 m. The whole of the northern part of the mountain is composed of Pre-Cambrian grits, sandstones and some slaty shales. These rocks are lifted up along a large boundary fault against the surrounding plain, which is paved with beds of Sinian, Cambrian, Ordovician, Silurian, Middle Carboniferous, Permian and Tertiary ages.

Upon the floor of these bed-rocks rests a boulder-bearing clay. The latter sometimes plasters against the hillsides formed of ancient strata, and sometimes forms a drumlin-like lobe without disclosing any nucleus of bed-rock, and is often capped by a reddish loam comparable with the Siashu Loam in the Nanking area. Of the specimens of land shells recently collected from the Siashu Loam only a few are extinct forms. This indicates a very recent age for the Siashu Loam, and consequently for the loam of the Lushan, probably equivalent to the Malan Loess of northern China.

FIG. 82. Striated surface produced on the Middle Carboniferous limestone, east of the Lushan. (By courtesy of DR. G. B. BARBOUR.)

At a point on the shore of the Poyang Lake, near the Frog Rock, over nine kilometres from the foot of the mountain, a section of the clay with boulders and of the floor on which it rests is well exposed. The floor is composed of a thick and well-bedded limestone of Middle Carboniferous age, exceedingly pure and rather hard. Bedding planes of the limestone are clearly developed, and they dip regularly at about 20° away from the lake, namely, to the north-west. At the end of the hill-spur which is entirely formed by the boulder-bearing clay deposit, a wavy surface of the limestone, about 25 feet wide and 7 feet long, cuts across the bedding planes, and is marked by long grooves and scratches running generally south-east. Parts of the surface tend to curve up towards the lake side, and parts of it tend to slope down in the same direction. As a whole its position is nearly horizontal. The finer scratches are almost obliterated through weathering, but the deeper grooves are clearly recognizable. Exhaustive search in the neighbourhood has failed to detect any sign of a horizontal dislocation which might have produced such a surface. On the other hand, its general appearance (see *Fig.* 82) vividly recalls glacial pavements in glaciated countries. Dr. Barbour, however, holds that if the surface were due to glacial action, it could not have survived the deep weathering processes that have operated since. He therefore argues that another explanation must be sought.

The boulders, pebbles and angular fragments of rocks scattered in the clay are all derived from the mountain. They have evidently undergone weathering which appears to be more effective as regards the clay and much less so in the boulders of grit. The latter are almost entirely composed of coarse grains of quartz cemented by silica, and therefore much less susceptible to chemical disintegration. The occurrence of small fragments of shale and slate indicates that these two are highly resistant to the weathering process; otherwise they could not have remained in their original form. Of all the rock types occurring in the northern part of the Lushan the sandstones of the Kuniuling Series are most prone to weathering. Some of these do occur in the clay as scattered boulders, and are often rotted to the core. Yet they retain their original shape in the otherwise homogeneous clay. Chemical and microscopic analyses of random samples of the clay, not only from Lushan but also from similar deposits in other parts of the Lower Yangtze Valley, reveal a striking homogeneity. Texturally it is almost indistinguishable from the Nantou Tillite of Pre-Cambrian age.

These and other facts converge to show that the ferruginous element in the clay may have been transformed into a higher state of oxidation since its deposition, and may have even undergone incipient lateritization in its crustal part (of this the chemical evidence is still inconclusive), but the evidence is decidedly against the possibility that the clay was produced through thorough weathering of the coarse materials that it contains or of the bed-rocks on which it rests.

Among the smaller pebbles there occur large subangular blocks 4 to 5 feet across. No sign of assortment of the material is to be found. Nor can we detect any similarity in the nature of the deposits to those resulting from the land-slips at Kander and Flims in the Alps, or to those from the collapse of the Old Red Sandstone of northern Britain in Palæozoic times.

The question with which we are mainly concerned here is the means of their transport. Either the formation of extensive dry fans or solifluction might be reasonably assumed. To explore these possibilities, a profile is drawn of the sub-surface of the boulder-bearing clay, extending from the mouth of the nearest valley which comes down from the mountain to the shore of the Poyang Lake where the section is exposed. This profile (*Fig.* 81) shows that the gradient between the two points taken as a whole is hardly perceptible. The shape of the floor that it reveals is so irregular that it is difficult to conceive how large blocks of the size mentioned could have been transported over that distance either through solifluction or as a result of the formation of a fan. In the case of a fan-deposit a gradational arrangement of material according to the distance traversed would have been more or less inevitable. The larger boulders or blocks would have been deposited closer to the mountain, while those of finer grade would be spread farther out, whereas the boulders occurring near the lake shore are, as a whole, considerably larger in size than those found nearer to the mountain. That the deposit is entirely devoid of any trace of layering is also opposed to the idea of deposition as successive fans.

Solifluction might be less objectionably assumed as the alternative means of transport. The difficulty is, however, by no means less formidable. If a comparison be made between a typical and highly instructive case of solifluction, as recently described by Russell, and the Lushan deposit, one can hardly find any common feature either in the nature of the material or in the shape of the ground. There is no well-graded slope on the eastern side of the Lushan to enable solifluction to take place on that extensive scale, nor could there have ever existed a solifluction slope in recent geological times, because the mountain is separated from the plain

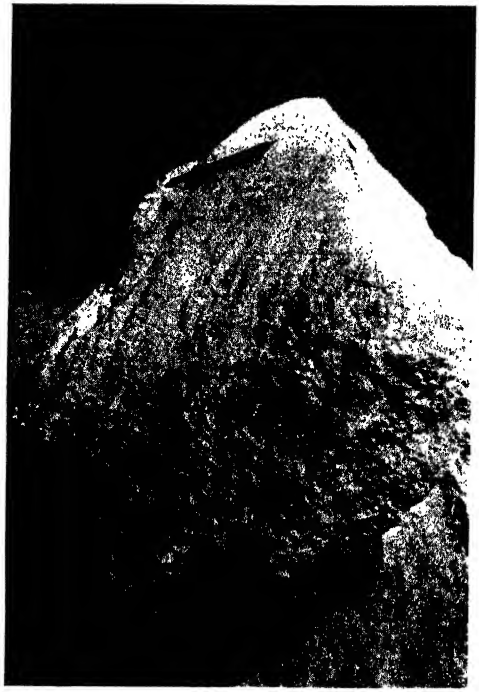

FIG. 83. Striated boulder found in the western valley of the Lushan. (By courtesy of DR. G. B. BARBOUR.)

by a mighty boundary fault of the pivoted type. If the tectonic forces have been recently active they would have tended to increase the gradient from the foot of the mountain to the lake shore instead of decreasing it. Assuming, for the sake of argument, the sub-surface of the boulder-bearing clay has essentially remained stationary, it is still questionable whether an actual case has ever been described where solifluction has transported material across a region of such relief and to such a distance.

At another point on the lake shore, some 7 km. from the foot of the mountain, gigantic blocks of the Lushan rocks are piled up, resting on the Red Sandstone. That the subsurface on which these jagged blocks lie actually rises to a higher altitude than toward the mountain side is a fact of some interest. They strongly recall the so-called "Blockpackung" in German literature.

FIG. 84. General view of the Wangchiapo Valley, northern Lushan, looking eastward. Note the gulley cut subsequently to the formation of the U-shaped valley.

A third point, named Hsinchiao, on the northern side of the mountain, offers some features of special interest. The place is about 3.5 km. from the foot of the mountain. There a small isolated hill composed of the usual boulder-bearing clay stands by the side of a brook, which demonstrates that the strength of the present stream is utterly inadequate to convey the boulders. The young deposit rests on the Silurian sandstone. Unfortunately its surface is nowhere disclosed though the contact is clearly seen. A part of the boulder-bearing clay is superficially thrust upon the same material, indicating an intra-formational movement. To the north of this deposit occur gravels which might represent the outwash if the boulders and clay of Hsinchiao are to be accepted as a "Stauchendmorän" of German authors.

On the western side of the mountain the same clay with boulders is developed, apparently merging into the Red Loam. The boulders and pebbles frequently show one or two well polished surfaces which, now and then, are marked by faint striation. But these can hardly be relied upon as evidence of glacial transport. The boulder-bearing clay is here and there overlain, on the western side of the mountains, by gravels, as is usually the case in a complete glacial sequence.

In the Lushan itself there are a number of features that deserve some consideration. A large U-shaped valley called Wangchiapo starts from the watershed of the northern part of the mountain and leads down to the plain on the north-eastern foot. In that plain the red boulder-bearing clay spreads out far and wide. Those sections on the lake shore already discussed furnish some idea as to the nature of the material and its natural profile. The bottom of the U-shaped valley is deeply trenched by the mountain stream, revealing the bedded grit partially covered by boulder-bearing clay almost identical with the material that occurs in the plain. In the higher reaches there are several hanging valleys along the side of the great U-valley. At the head of one of the hanging valleys opens out a funnel-shaped hollow space, suggesting a slightly demolished cirque. Features of this kind are rather frequently met with in the northern part of the mountain. As they clearly differ in shape from the stream cuttings occurring near by or subsequent to their formation, it seems natural to assume some erosive agency once active that differed in kind from the mountain streams as we see them in operation to-day. It is true that some of the U-valleys are under structural control. But this fact does not explain away the obvious morphological difference; for some of the V-valleys are likewise under structural control. Under similar conditions why should then a U-valley be generated in one place or at one time, and a V-valley be brought about in its immediate neighbourhood, or even inside it, in a subsequent epoch? In a number of cases closely examined only a veneer of the debris material plasters the bed-rock floor of the U-valley. The smooth curve cannot, therefore, be attributed to subsequent filling. On the other hand, no trace of deposit either of lateral or terminal moraine is found in those valleys. A dissected ridge running across one of the suspected valleys was formerly taken to be a bank of "boulder clay," but closer examination has proved that it consists of

FIG. 85. An artificial exposure of clay-and-boulder deposit on the Tungliu Terrace, showing subangular erratics and the unstratified nature of the deposit.

bed-rock. In the case of the great U-valley of Wangchiapo, the gathering ground at the head of the valley does not appear to be sufficiently large to form the necessary névé of a glacier big enough to have eroded the valley.

Among boulders in the valley only two specimens have been found that possess a polished and striated surface. After a joint inspection with G. B. Barbour and E. Norin, we agreed that one of those might have been glacially produced; but as to the other, opinions differ regarding its origin. One must admit that striation on boulders is always more or less difficult to judge even in the eyes of experienced glacialists. The systematic study of Engeln on the matter affords some criteria worthy of our consideration. According to Engeln, most of the glacially striated boulders known from various parts of the world possess a more or less triangular surface on which the striæ are generally more distinct, with finer striæ on the posterior part, namely, that part of the scratched area close to the base opposite to the acute triangle, and generally heavily rubbed in the anterior part, that is, in

FIG. 86. Clay-and-boulder deposit on the Tungliu Terrace, Central Yangtze, with jagged boulders of silicified limestone of distant origin.

the region near the acute apex. Our questionable striated boulder conforms with this description.

The clay-and-boulders is a formation not restricted to the Lushan area, but is distributed further down in the Yangtze Valley. Some 70 miles below the Lushan along the Yangtze River, a terrace, about 20 m. high, stretches out to a considerable extent. In the neighbourhood of Tungliu city, the terrace is entirely covered by the boulder-bearing clay, which, in turn, is here and there clad by a mantle of loam. The country is entirely open. Mountains rising to a height of 800 to 900 m. loom on the distant horizon to the south. They are probably 25 to 30 km. away from the terrace. In the tenacious clay are scattered pebbles and boulders exhibiting no trace of stratification except in the lower part of the deposit which here and there is rudely bedded. The pebbles consist of silicified Sinian limestone, buff and purple quartzites probably of Lower Carboniferous and Rhætic ages, respectively, argillaceous limestone possibly belonging to the Cambrian, vein quartz, etc. The larger boulders are usually over one foot in diameter. But those measuring 7 to 8 feet in girth are not uncommon. They are jagged in shape, and are rounded only at the edges and corners. These large boulders are always associated with smaller sub-rounded ones as well as small pebbles, forming an intimate mixture with a clayey matrix.

The floor of the terrace is composed of inclined strata of Tertiary Red Sandstone and Moscovian limestone. Satisfactory evidence has been secured that this mixture of coarse and fine materials can neither be derived from the floor on which they rest nor from sources lying near. Behind the terrace, and separating it from the hinterland, is an extensive lake. Even if we assume that the lake came into existence only in recent times, we still have to find an adequate means of transport of rocks, 7 to 8 feet in girth, across an extensive country on an essentially level surface. Apart from the question of the origin of the clay, the boulders constitute a problem that must be dealt with *per se*.

Fan deposition is here out of the question, for the highland is too far away. Solifluction is hardly more conceivable in those circumstances. The material forms a continuous, extensive sheet, and is not deposited along a channel. This, together with the general absence of stratification and the lack of assortment of material into grades, presents a formidable objection against postulating river transport. Moreover, fluviatile gravels and sands do occur in the lower extension of the terrace, about 10 km. along the river below the city of Tungliu. If they are both of fluviatile origin, why then are the usual characteristics of water-borne deposits clearly exhibited in one place, and thoroughly lacking in another which is situated close by?

A similar state of affairs can be followed all along the riverside throughout central Anhui. The boulder-clay-like deposit is sometimes covered by the Red or Reddish Loam apparently comparable with similar kinds of deposits in northern China. In one or two places the drift clay-and-boulders is divided into two parts by a weathered surface of a wavy shape. The lower part of the deposit, with its wavy

FIG. 87. The cirque-like depression on the top of the Kiuhuashan, southern Anhui, with a U-shaped valley leading to the north.

surface, is in a few instances rendered "bayonet-form," cutting into the upper part. In such instances we can hardly doubt that it had undergone an intra-formational movement.

Turning again to the morphological side of the problem, one must naturally treat that subject with reserve, and should not, as already said, attach any undue importance to any conclusion derived therefrom at the present stage of inquiry. The features in the Kiuhuashan (about lat. 30° 32′ N., long. 117° 40′ E.), southern Anhui, happen, however, to be so well preserved, and the structure is so peculiarly suitable for morphological discussion, that it would be unjust to leave it out of consideration.

The Kiuhuashan is among the northernmost of the group of mountains in south-eastern Anhui on the southern side of the Yangtze. It is entirely composed of a rather coarse-grained granite, wonderfully homogeneous in composition. On the top of this mountain is developed a subcircular doline-like depression with a single opening to the north. The depression is surrounded on all sides by a fairly steep wall, except for the gap through which the water drains to the north. The bottom of the basin is rather flat, affording a splendid site for Buddhist monasteries. An altitude of about 500 m. above sea-level was recorded by barometer at the bottom, and 530-560 m. at the top, of the surrounding wall. The southern wall is particularly steep and notably higher than the rest, being 590 m. above sea-level. The circumference of the depression cannot be less than 3·5 km. as measured on the top of the surrounding wall.

The northern gap is immediately connected to a U-shaped valley with rather well developed shoulders, which leads down to the northern foot of the mountain and which is slightly dissected by the stream at the bottom. In the U-valley are numerous perched blocks of granite which sometimes reach an enormous size, and between which the present stream trickles through. The southern part of the mountain is connected with a higher and plateau-like mountain called the Tientaishan, rising to an altitude of 900 m. The main drainage of these mountains winds round between the Kiuhua and the Tientai, and cuts a deep and sharp V-valley in which roars the main stream that runs to the north. The U-shaped valley on the northern side of the Kiuhuashan hangs to this main valley near the northern foot of the mountain.

Below the Kiuhuashan, and on the northern side of it, a plain opens out. In this mountain-locked plain runs the river which has its main headwaters in between the Kiuhuashan and Tientaishan. After travelling through fans sent down by the lateral streams, the main river almost reaches its base level in the open plain, where a reddish sandy clay carrying large and small boulders is spread out far and wide. Occasionally it forms dissected terraces standing some 10 m., or at most 15 m., above the river bed.

All along the river course large boulders together with small pebbles are found in abundance. They are partly brought down directly from the mountains by the present stream, and partly washed out by it from the boulder-bearing clay through which it flows. At a point some 5 to 6 km.

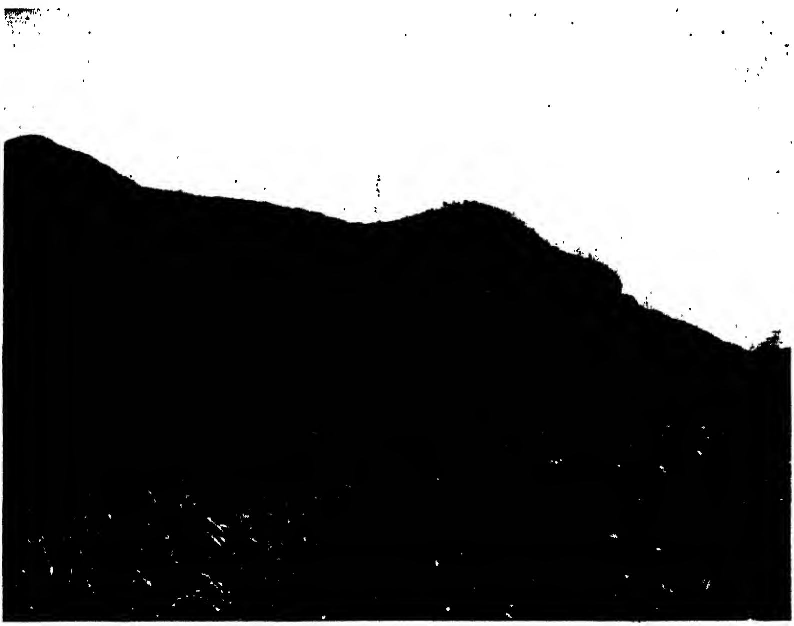

FIG. 88. The Tsienmaotien depression on the top of the northern part of the Tienmongshan, northern Chekiang, half-filled with clays.

from the foot of the mountain the average size of the boulders carried by the river proves to be considerably smaller than those occurring in association with the clay. There, the largest boulders found in the river bed are not more than 2·5 feet in girth, while those mixed with the clay exposed in places close by are usually 6 to 8 feet in girth. Blocks having the size of 12 to 15 feet in girth are also not rare. The large boulders spread out to a distance of 7 to 8 km. from the foot of the mountain.

Here, without invoking ice action, it is almost equally difficult to account for the boulders as it is to explain the development of the U-shaped valley and the subcircular depression on the top of the Kiuhuashan, to which even the most critical observer could hardly deny the name cirque.

Some more notable features are developed in the Tienmongshan (about lat. 30° 25′ N., long. 119° 20′ E.) on the southern side of the Taihu basin. The whole mountain mass

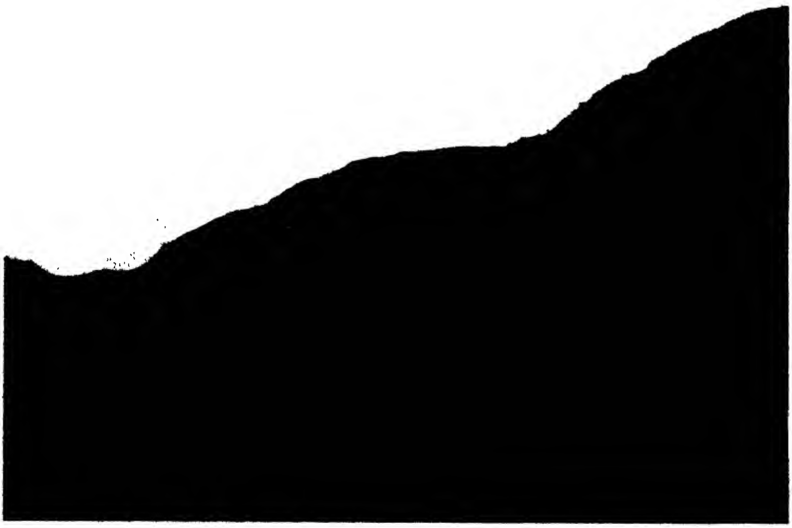

Fig. 89. The U-shaped saddle between the Tsienmaotien depression and the U-shaped valley on its eastern side. Note that the bedded rhyolite is exposed in the bottom of the valley.

is composed of well-bedded rhyolite which often develops prismatic joints. Consequently stout columns of the rock are often cleaved off. Up to the height of 800 m. deeply incised valleys and precipices characterize the scenery. Above that height, the topographical features become decidedly softer. Rolling plateaux and broad valleys dominate the landscape.

In the northern heights, at an altitude of about 1,380 m., a small tarn occurs, which is now filled up by yellowish and reddish clays at the bottom on which grows sphagnum moss. Surrounding the tarn are heights varying from 30 to 80 m. above its bottom. Although its original depth is not definitely known, the evidence is fairly conclusive that it contained a considerable volume of water in days gone by. There are three gaps in the surrounding heights. The one

FIG. 90. A dry U-shaped valley (descending eastwards) from the Tsienmaotien depression.

on its western side now affords the only drainage of the basin, and has been evidently excavated by an active stream running down the western slope of the mountain that has headed back in the course of time. From the rock spur left between the cliffs standing on both sides of the cavernous trench cut by the stream, one can easily restore the shape of the original headwall of the cirque-like depression. The second gap leads to a broadly curved valley towards the north-east. It is now entirely dry. The third gap, which is the most impressive, is situated on the eastern-side of the tarn. Bedded rhyolite is exposed to its bottom, which stands distinctly higher than the original bottom of the tarn. This gap leads down to a dry U-shaped valley on the eastern side. Neither structural control nor talus filling would come into the question as to the development of the U-valley; for the bedded rhyolite is only here and there covered by thin layers of surface debris. On the southern side of the height that

FIG. 91. Pachotsien, on the northern foot of the Tienmongshan, showing the form of a nivation cirque.

forms the main watershed of that part of the mountain another broadly curved valley descends to the south. Among the scattered debris occurring in that valley T. Y. Yu found a number of scratched boulders, which, unfortunately, the writer has been unable to examine. Features ascribable to the action of slowly melting snow under a cold and rather humid climate, as described by Russell under the term "nivation cirque," have been found to have extended down even to near the northern foot of the mountain.

An extensive plain stretches out on the northern side of the mountain. Roundish hillocks representing a sculptured terrace, 25 to 35 m. high, are scattered on both sides of the main valley. Sometimes they bear a mantle of a clay with rhyolite boulders of all sizes and without definite arrangement; and sometimes the floor of a brownish shale probably of Cambrian age is laid bare. Angular blocks of rhyolite over 4 feet across are found on the hill tops resting on the shale some 4 km. away from the foot of the mountain. "Laminated clays" are reported to occur at two localities. The one near the city of Hsiaofeng, where the writer made a close examination, proves, however, not to be a typical varve clay.

The point that requires serious consideration in connection with the loose deposit in the Hsiaofeng Plain is the occurrence of the clay with boulders of rhyolite on the tops of the hills and large boulders in the river bed. They reach a distance of no less than 23 km. from the mountain. Stout prismatic blocks of rhyolite, 10 to 12 feet in girth, are now and then found among much smaller and well-rounded pebbles of the same rock together with chips of other rocks. It might seem at first that the river could actually transport such large blocks to that distance across a plain either under normal conditions or when flooded by torrential rain. The hypothesis of river transport encounters, however, certain difficulties: (1) The torrent in flood might possibly move the large blocks in its mountain course, but as soon as it emerges on to the plain the torrent tends to flood it, and consequently there must be a sudden drop of velocity with immediate deposition of all heavy material. (2) If the large angular blocks were really rolled in water for a distance of more than 20 km., can they still retain that prismatic shape? (3) Can a river deposit be devoid of bedding, without any grading of its material, or without layers of sand or gravel? (4) Whence and how is the clay derived which is in association with the boulders? The last point constitutes the kernel of the problem. It might be supposed that the clay is but a transformed product through weathering of the rhyolite boulders as well as of materials of finer grade. That this is unlikely is demonstrated in many sections where the rhyolite boulders are thoroughly weathered in the clay but still retain their original shape. Moreover, weathering does not always completely destroy stratification, as testified by the weathered Tatung Conglomerate occurring in the Lower Yangtze Valley. Chemical analyses of the weathered boulders might throw some light on the problem. But these remain to be carried out. As regards the clay itself, a few analyses have been made, but they lead to no conclusion as regards its origin. Microscope-sections show, however, a peculiar resemblance between the clay in question and the matrix of the Nantou Tillite, which has been generally accepted as of glacial origin.

These few examples illustrate the types of problem in hand. Obviously they cannot be satisfactorily dealt with in a simple and general way. In the Lushan and Kiuhuashan areas solifluction or extensive fan-deposition might be cited as possible processes in producing the clay-and-boulders; but in central Anhui and the Hsiaofeng Plain, north of the Tienmongshan, weathered residues, with or without the accompaniment of "colluviation," piedmont fanning, and solifluction, obviously cannot account for the origin of that extraordinary deposit. Unless there is reason to hope for the discovery of a hitherto unknown means of transport, it would seem that we are forced to face the alternatives: either flowing water or moving ice. It remains to be demonstrated that rivers can convey such boulders as described, and then deposit at the same time boulders and fine clay without leaving any trace of stratification or layers of sand in the deposits thrown down by them. With the hypothesis of ice action in pre-Red-Loam times those difficulties at once disappear. Such a hypothesis would also account for the generation of the extensive sheets of gravels that underlie the Red Loam in the Lower Yangtze Valley.

Solifluction might have indeed played a part along some of the mountain slopes in producing some of the materials that have been tentatively named as boulder clay. But if we admit solifluction taking place on an extensive scale in low ground, it is a *sine qua non* to admit glaciation in high mountains. The reason is as follows. Solifluction, as originally defined by J. G. Andersson, involves slow flow of rock-debris under wet conditions; namely, in regions where there is abundant rainfall or melting snow. And in a typical case described by Russell a high frequency of freezing is recorded, amounting to no less than two-thirds of the number of days in each year. If the low ground is exposed to such semi-arctic temperatures, and if the region receives abundant precipitation, it is not difficult to perceive that glaciers would form in high mountains.

A discussion with reference to a particular case will render the argument more tangible. According to the rain chart compiled by H. v. Wissmann (also see *Fig.* 4, p. 6), the highest annual precipitation in northern and central China falls in the region of the Lower Yangtze Valley, including the Lushan area, which, according to Dr. Chu-Coh-Chin, registers a maximum of some 2,000 mm. per year. Unlike northern China, the rainfall is not restricted to the summer season, though maxima occur in that season under present climatic conditions. There would be, therefore, generally, a sufficient humidity to moisten the ground and enable the process of solifluction to take place, provided that there is reason to believe that a similar amount of annual precipitation prevailed in recent geological times. Putting the issue in another form, if there had been wet periods as required by solifluction, the Lushan area would certainly be one of those that received a high precipitation. The fact that the extensive gravel beds laterally merge into the suspected boulder clay certainly demonstrates a rather high precipitation at the time when these essentially contemporaneous deposits were formed.

Within the present temperature range throughout the year, solifluction is, however, nowhere observed on the slopes of the mountain where that phenomenon is likely to occur if it occurs at all. This would seem to confirm the general belief that a climatic condition involving repeated freezing and thawing is necessary for solifluction to take place. Allowing 100 m. of altitude for a lowering of temperature of one degree Centigrade, then the higher part of the mountain would be some 10 to 15 degrees lower in temperature than the surrounding plain. If such a generally low temperature prevailed in the plain as to be able to promote solifluction, then glacial conditions would be hardly avoidable in the high mountains. Thus the process of solifluction cited as an argument against glaciation turns out to be one rather in favour of it.

Here we have given a reason, on the basis of the present distribution of precipitation, as to why the suspected glacial deposits are particularly well developed in the Lower Yangtze Valley. Precipitation and low temperature are, however, not the only factors that determine the development of mountain glaciers. There must be enough area in the higher part of the mountain to collect the snow to form a névé. This explains why on the northern side of the Lower Yangtze the peaks of the Huaiyang Range, rising to a height comparable with the Lushan, are devoid of any of the suspected features. Nor is the debris deposit at the foot of those heights similar in nature to the so-called clay-and-boulders. That this suspected glacial deposit is largely restricted to the northern side of the high mountains, and that the unusual topographical features which they possess are also confined to their northern part, are further points worth some consideration. It is perhaps still premature to regard glaciation in the Lower Yangtze Valley as proved. Nevertheless, the balance of evidence seems to point strongly to this conclusion.

Lowering of the Snow-line over Eastern Asia in Pleistocene Time

Let us now view the problem in a broader perspective, and look into the countries surrounding the Lower Yangtze region regarding the evidence of change of temperature in recent geological times. The extensive glaciation in Siberia which has been recently confirmed need not come into our discussion, for that region lies far to the north. The cirques of the Tapeishan in the northern part of the western Tsinling offer some evidence, however, from the point of view of the problem in hand. Inasmuch as the Tsinling carries such conclusive evidence of recent uplifting along its northern boundary fault as is indicated by the presence of tectonic hanging valleys, the altitude of those cirques must have been much lower in glacial times as compared with that of the plain. The difference in height between the top of the mountain and the northern plain now amounts to 2,700 m., as measured by an aneroid barometer. How far the vanished glaciers came down is, however, a point for further critical study.

Still more important is the result obtained by Dr. Heim in the high mountains of western China, especially in the

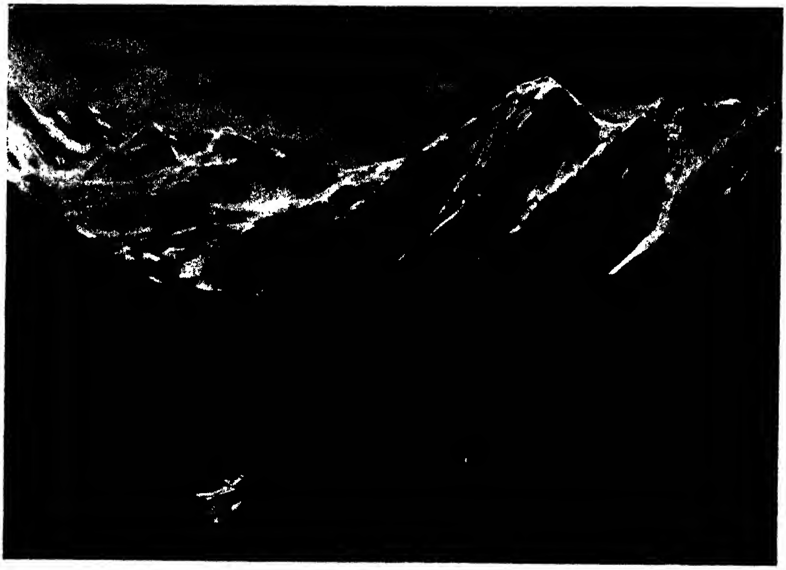

FIG. 92. Najambö Gongkar and Great Gomba Glacier. (By courtesy of DR. ARNOLD HEIM.)

Kuanhsien area (about lat. 31° N., long. 103° 30′ E.), where the Diluvial moraine lies over 1,000 m. below the front of the existing glaciers. Deeply dissected fluvio-glacial deposits are found in places lower than the Mosimien Terrace, which stands at an altitude of 1,600 m. From these and other related facts the author of the "Minya Gongkar" rightly concludes that the region of the Tibetan border has recently undergone a general uplifting. That the amount of uplifting has been considerable may be further inferred from the depth of the valley that has been incised by the Tungho, which passes close by. According to Heim the Mosimien Terrace stands some 600 m. higher than the Tungho Valley, which receives the water from the valley of the Luho immediately below Mosimien. It would thus seem that the old moraine as observed by Heim lay at a much lower altitude in Diluvial time than it does at present.

Traces of recent glaciation have been noticed in the mountains of Yunnan by Gregory and W. Credner. The lowest of these so far found occurs at an elevation of 3,800 m. Comparing it with the altitude of the existing glaciers, Credner came to the conclusion that a Diluvial lowering of the snow-line must have amounted to at least 1,500 m. In the high mountains and dissected plateaux of Yunnan there is abundant evidence of recent elevation, estimated by Deprat at 2,000 m. Although the exact amount of uplifting requires more careful investigation, it can hardly be doubted that the highland of Yunnan has been elevated to a considerable extent in late Pleistocene times. It will be realized that the Lungtsonfang area that was examined by Credner for former glaciation is situated more than 3° of latitude south of the high mountains of the Lower Yangtze region, yet it would fall to a height comparable with the Yangtze mountains if the amount of recent elevation deduced by Deprat be deducted. As far as the question of latitude and altitude is concerned, the Yunnan case seems to have an important bearing on the climatic problem of the Lower Yangtze.

The problem of recent glaciation in the "Alps of Central Japan" was first announced by John Milne. Very little attention, however, was aroused thereby. Only in recent years have T. Ogawa, H. Matsumoto, J. Takahashi, and others studied the problem, with amazing results. From the evidence available it would seem probable that not only in the high mountains in Central Japan, but in part of the lowland also, a few hundreds of metres above sea-level, there is evidence of glacial and interglacial conditions. As meteorological data show that the present climatic conditions in Central Japan and those in the Lower Yangtze provinces are much alike and closely connected, the problem of climatic changes in one of these regions must naturally be considered in conjunction with the other.

Thus we have an established zone of cold climate closing in on eastern China some time in the Pleistocene period. In such circumstances, the region under consideration cannot but have been exposed to the wave of cold. Unless evidence be brought forward to show that there was a continued desiccation it will be difficult to rule out the possibility, nay, the probability of glaciation in the Lower Yangtze Valley. Such a cold period was most probably succeeded by a period of genial or even sub-tropical climate, resulting in the high oxidation of the ferruginous soil and incipient lateritization of the boulder-clay-like deposit and the Red Loams. This warm period has been generally recognized, and, therefore, needs no further discussion. With these facts in view it does not appear to be necessary to assume an altered geographical position of the equator during the Quaternary Ice Age so as to account for the alleged absence of glaciation in China.

ADDENDUM.—While this work has been in the press, the author has been fortunate enough to find indisputable evidence of glaciation in certain parts of the Yangtze Valley. In the Huangshan, southern Anhui (long. 118° 8′ E., lat. 30° 10′ N.), parallel grooves and furrows were observed at an altitude of 960 m. on the wall of a hanging valley of U-shape. They are rather deeply engraved in the otherwise uniform and smooth granite surface which was, no doubt, abraded by ice. Their slight inclination towards the lower part of the valley indicates the movement of the ice. A boulder of a fine-grained granite, with two opposite faces rubbed and sharply scratched, was also found in the same mountain.

A detailed investigation made in the Lushan area has resulted in the finding of numerous striated boulders of the hardest rock-type among the material described in the present chapter in terms of " clay-and-boulders " and " boulder-clay-like deposits." The ice-scratched boulders occur both in the mountain and in the surrounding plain. *Roches moutonnées* and glacial pavements are well developed on the shores of the Poyang Lake. The unusually low water in 1936 gave an opportunity for observation. Dissected end-moraines were at the same time recognized. With them are associated extensive sheets of outwash material. It has been further established that three successive glaciations took place. The oldest, and also the largest, is named the Poyang glaciation, and the next the Taku glaciation. In both of these glaciations piedmont glaciers were formed. The third, which produced only small glaciers in the higher parts of the mountain, may well be called the Lushan glaciation. These glaciations were separated from each other by interglacial periods during which different grades of incipient lateritization affected the material previously deposited. Extensive distribution of fluvio-glacial gravels due to the early glaciations paves an avenue for further research. For instance, the Yuhuatai Gravel in the Lower Yangtze Valley and the Yaan Gravel in the Red Basin of Szechuan may eventually prove to be of similar origin.

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CHAPTER X

REGIONAL STRATIGRAPHY

In the present chapter a generalized account is given of the stratigraphical development in different regions of China. Each stratigraphical division in a given area will be briefly described and supplemented with a list of leading fossils as they have been found and identified. In some, and perhaps the majority, of cases the description given is essentially verified by the writer's own experience, but in others he cannot claim any first-hand knowledge. At all events, an extensive list of references is attached to this chapter with a view to enabling the reader to refer to the original source of information.

It is hardly necessary to say that each of the formations to be dealt with in this comprehensive summary generally covers large stratigraphical units. They are obviously capable of further division, at least in certain cases, even in the present state of our knowledge. No sub-division is, however, attempted, partly to save space and partly to focus our attention on the larger issues involved in the development of geosynclines and the broad demarkation between marine and continental periods. A third reason is connected with our method of treatment. The greater the detail to which we carry out our stratigraphical classification, the less fit it would be for regional generalization. In a country like China, where large areas are yet to be geologically mapped, a convenient method to obtain some notion as to the distribution of the different formations would be to tabulate them in their natural succession so long as the formations are of general character for a particular region. Following this procedure the sacrifice of some stratigraphical detail or information concerning local variation in facies is more or less inevitable. Briefly speaking, our present object is to coordinate what is actually known from region to region in

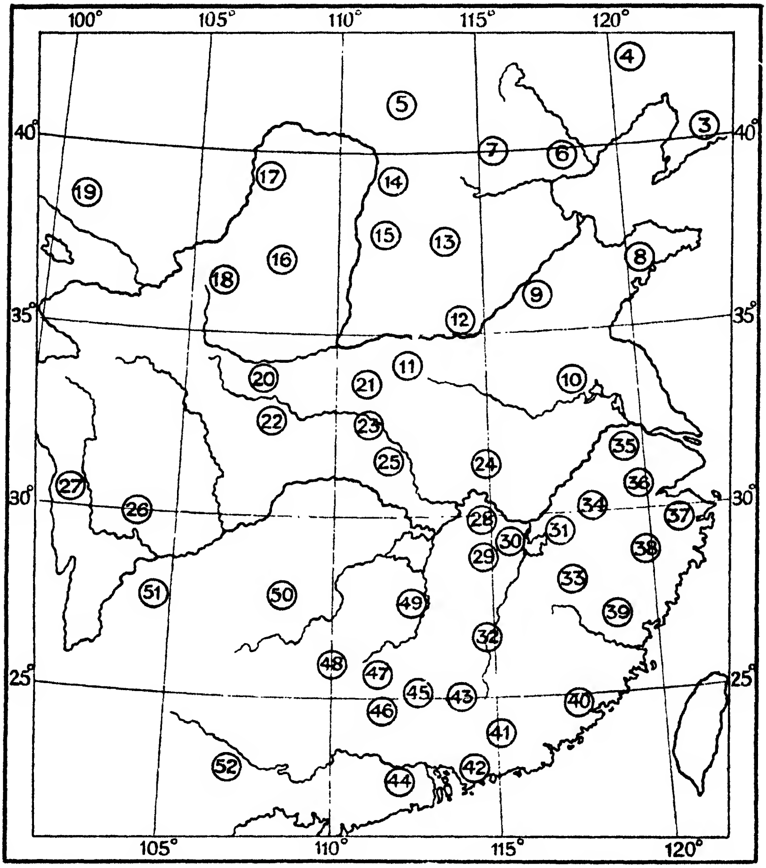

FIG. 93. Key Map to Regions (the numbers correspond with those used in Chapter X).

(3) S. Manchuria
(4) S. Khingan and Jehol
(5) Inshan Range
(6) N.E. Hopei.
(7) Western Hills of Peking
(8) E. Shantung
(9) W. Shantung
(10) N. Kiangsu
(11) Central Honan
(12) N. Honan
(13) Central Taihang Range
(14) N. Shansi
(15) Central Shansi
(16) Shensi Basin
(17) Alashan and Ordos
(18) E. Kansu
(19) N.W. Kansu
(20) W. Tsinling
(21) Eastern part of the Middle Tsinling
(22) N. Szechuan and Tapashan
(23) N.W. Hupeh
(24) Tapeishan, N.E. Hupeh
(25) Central and W. Hupeh
(26) S.W. Szechuan and the Red Basin
(27) E. Sikang
(28) S.E. Hupeh
(29) N.W. Kiangsi
(30) Lushan Area, N. Kiangsi
(31) N.E. Kiangsi
(32) S.W. Kiangsi
(33) S.E. Kiangsi
(34) S. Anhui
(35) Nanking Hills
(36) N.W. Chekiang
(37) E. Chekiang
(38) S.W. Chekiang
(39) N. Fukien
(40) S. Fukien
(41) E. Kuangtung
(42) Hong Kong and its Neighbourhood
(43) N. Kuangtung
(44) W. Kuangtung
(45) Middle part of the E. Nanling
(46) Mengchuling (Central Nanling)
(47) Tupangling (Central Nanling)
(48) N. Kuangsi and Mid-W Nanling
(49) Central and E. Hunan
(50) Kweichow Plateau
(51) E and Central Yunnan
(52) S.W. Kuangsi
(53) W. Yunnan

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order to indicate what we need to know in the immediate future.

Enthusiasm in fossil hunting has sometimes led to the neglect of petrographical observation. After all, geology is primarily concerned with rocks. And field observations must precede laboratory work. If, in the following cataloguing of the different formations the lithological characteristics of each formation do not appear to be sufficiently indicated, this assemblage of data would serve to show why and how the geologists working in China should modify their attitude in collecting information from the field. The fossils listed here in connection with a given formation are not all of the same value as regards their accuracy of determination or identification. It is, however, generally true that when a species already known elsewhere in the world is listed, its affinity with that known form is hardly in doubt, although the question of specific identity cannot always be taken for granted. Fossils collected and described without clear reference to the stratigraphical relation of the strata in which they occur have often proved to be of limited value from the geologist's point of view. Many of the fossils collected in that way are excluded from the list in the following pages.

Throughout this chapter a number of conventions are followed. The sequence is always described in descending order. Undulatory lines indicate clearly recognized stratigraphical discordance, and broken lines uncertain or ill-defined boundaries. Local stratigraphical terms are used wherever available. The thickness and geological age of each formation are indicated whenever possible.

(1) Mongolia

Gobi Gravel. "Residual gravel," usually containing some sand and clay; widespread all over the Gobi region. Thickness rarely reaching 1.5 m.

M. Pliocene

Ertemte Deposit. Whitish clays, sands and gravels occurring in indistinct layers or as a mixture, with one facies merging into another within a short distance. The clayey layers usually contain numerous concretionary bodies, and the coarse layers yield abundant fragments of bones. Fresh-water shells are also met with. On faunal grounds the Ertemte deposit is correlated with the Dalainor deposit immediately underlying the basalt. Animal remains obtained from

M. PLIOCENE

these localities have been known as the Ertemte fauna, the leading elements of which are: *Gazella blacki* TEILH. and YOUNG, *Prosiphneus intermedius* TEILH. and YOUNG, *Lepus annectus* SCHLOSSER, *Castor zdanskyi* YOUNG, *Hipparion* and deer, the last-named two being larger in size than those found in the Sanmen Beds of Lower Pliocene age.

[NOTE.—Ertemte is the name of a small hill, about 17 km. north of Hallong-Osso, which place is located 115 km. N.N.W. of Kalgan.]

MIOCENE

Tunggur Formation. Sands or sandy clays interbedded with fresh-water limestone. The sands are often false-bedded, being sometimes intercalated with layers of peat. *Planorbis* and unionids occur in the fresh-water limestone. Mammalian bones abound in certain horizons. They belong to *Mus, Rhinoceros, Anchitherium, Chalicotherium, Hipparion, Antelope, Cervus, Mastodon, Platybelodon.* The last-named is a flat-tusked elephant. Its presence gives the fauna a more archaic character than the *Hipparion* fauna of the Lower Pliocene. Consequently it is believed to be of Miocene age. This formation is correlated with the **Hungkureh Formation** (sands and clays, with *Gazella, Hipparion, Mastodon,* and Rhinocerotids) in Outer Mongolia. Thickness in the type locality 45 m.

[NOTE.—Gur Tung Khara Usu, the type locality, is situated to the north-east of Irdin-Manha and east of Irendabasu on the Urga-Kalgan trail, about long. 112° 45′ E, lat. 43° 48′ N.]

Loh Formation. Green and brown sandy clays. Only developed in Outer Mongolia containing *Serridentinus mongoliensis* OSBORN, *Baluchitherium mongoliense* OSBORN. Probably Miocene. Thickness 300 m.?

OLIGOCENE

Baronsog and **Houldjin Formations.** The Baronsog Formation is typically developed near the Lama temple Baronsog, in the neighbourhood of the place where the Sair Usu trail and Irlien Ulan trail cross each other, about long. 110° E., lat. 42° 40′ N. It mainly consists of conglomerates and arkose sandstones of yellowish or greenish colour containing remains of a gigantic pig, *Entelodon,* and a hornless rhinoceros, *Baluchitherium,* of gigantic size. In Urtin Obo the formation has a thickness of 12 m., but in Duhum Usu its thickness is reduced to 2-4 m. This formation is correlated with the **Hsandagol Formation** in Outer Mongolia, where it consists of red sandy clays of great thickness. The **Houldjin Formation** is developed in the Irlien and Irdin-Manha districts and consists of greenish or yellowish sands and gravels with bones of *Baluchitherium, Titanotherium, Cadurcotherium, Entelodon* and fragments of a large tortoise.

Hsandagol fauna at Loh: *Hyænodon pervagus* MATTHEW and GRANGER, *Didymoconus colgatei* M. and G., *D. berkeyi* M. and G., *Amphicticeps shackelfordi* M. and G., *Bunælurus ulysses* M. and G., *B. parvulus* M. and G., *Palæoprionodon gracilis* M. and G., *Tsaganomys altaicus* M. and G., *Cyclomylus lohensis* M. and G., *Cricetops dormitor* M. and G., *Selenomys mimicus* M. and G., *Tataromys sigmodon* M. and G., *Desmatolagus robustus* M. and G., *Palæoscaptor rectus* M.

OLIGOCENE

and G., *Baluchitherium grangeri* OSBORN, *Macropelobatis osborni* NOBLE.

Ulan-Gochu Beds. Red and pinkish clays interstratified with white and grey sands characterized by the presence of *Embolotherium*. A few metres thick. Mainly distributed to the west of the Urga-Kalgan trail.

EOCENE

Shara-Muren Formation. White sands alternating with grey clays with *Protitanotherium mongoliense* OSBORN, *P. andrewsi* OSBORN, *Dolichorhinus*, and other faunal elements essentially similar to, but slightly more advanced than, those found in the underlying formation. Thickness 170 m.

Irdin-Manha Formation. Red, brown and grey clays occasionally intercalated with white sands. Fauna: *Desmatotherium mongoliense* OSBORN, *Lophialetes expeditus* MATTHEW and GRANGER, *L. minutus* M. and G., *Protitanotherium grangeri* OSBORN, *Dolichorhinus olseni* OSBORN, *Telmatherium berkeyi* OSBORN, *Gobiohyus* (2 spp.), *Eudinoceras mongoliense* OSBORN, *Andrewsarchus mongoliensis* OSBORN, *Hapalodectes servus* M. and G., *Hyænodon irdinensis* M. and G., *Propterodon irdinensis* M. and G., *Miacis invictus* M. and G. Thickness 12-34 m.

Arshanto Formation. Hard red clays, usually sandy and structureless, containing fragments of teeth belonging to small Lophiodonts. Thickness 5-30 m.

Duhum Formation. Upper part, arkose sandstones and gravels intercalated with fine and coarse sands, white, greenish or yellowish in colour, and red clay, about 12 m. thick; lower part, bedded red clay with lenses or banks of sandstone, 20-30 m. thick. Small perisodactyles are common in the lower part, and *Coryphodon, Lophialetes* in the upper part, being followed upward by the *Protitanotherium* horizon.

Gashato Formation. These beds are only known in the foot of the Gurbun Saikhan Range in Outer Mongolia, being characterized by the presence of archaic mammals such as Notoungulata, Multituberculata and Creodonta. Probably Palæocene. Thickness 100 m.

CRETACEOUS

Irendabasu Formation. Mainly sandstones, barren of fossils in the upper part, but the lower part contains predentate (probably duck-billed and bipedal) and carnivorous dinosaurs, including the *Ornithomimus* type, crocodiles, turtles of the *Trionyx* type, pelecypods and dinosaur eggs. Thickness 50 m.

Djadokhta Formation. Red friable sandstones and clayey sands containing *Protoceratops andrewsi* GRANGER and GREGORY, *Velociraptor mongoliensis* OSBORN, *Saurornithoides mongoliensis*, *Oviraptor philoceratops* OSBORN, *Shamosuchus djadochtænsis* MOOK, *Djadochtatherium matthewi* SIMPSON, and dinosaur eggs, probably those of

Protoceratops. Thickness 100-160 m. Typically developed at Shabarokh Usa, 50 miles east of Artsa Bogdo.

CRETACEOUS

Ondaisair Formation. Thin-bedded sandstones of buff or yellowish colour or white and papery black shales. The sandstones are rather coarse-grained, moderately indurated and often cross-bedded, becoming more prominent towards the lower part. This formation contains *Protiguanodon mongoliense* OSBORN, *Psittacosaurus mongoliensis* OSBORN, *Lycoptera middendorfi* MILLER, *Estheria middendorfi* JONES, *Ephemeropsis trisetalis* EICH., *E. melanurus* COCKERELL, *Cymatophlebis mongolica* COCK., *Trichopterella torta* COCK., *Indusia reisi* COCK., *Chironomopsis jobiensis* COCK., *Baiera furcata* (L. and H.), *Phyllocladites* (?) *morrisi* COCK., *Czekanowskia* sp. Exposed in the Ondai-Sair and Oshih Basins. Thickness 170 m.

Oshih Formation. Indurated mudstones and sandstones, reddish to buff in colour, yielding *Asiatosaurus mongoliensis* OSBORN, *Prodeinodon mongoliensis* OSBORN. Thickness 170 m.

Tsetsenwan Series. Conglomerates, well-bedded grey sandstones and shales with lava flows and tuffs, locally containing layers of coal and ill-preserved plants. Total thickness is estimated at no less than 8,000 m. Age: probably Jurassic.

PERMIAN

Lower Angara Series. Continental deposits presumably of Upper Permian Age are known in several places in northern Mongolia. They have yielded *Neurogangamopteris cardiopteroides* (SCHMALHAUSEN), *Nœggerathiopsis æqualis* (GOEPPERT), *Psygmophyllum potanini* (SCHMALH.), *Lepidodendron schmalhauseni* ZALESSKY in the Tannu Ula, and *Psygophyllum mongolicum* ZALESSKY, *P. potanini* (SCHMALH.), *Neurogangamopteris cardiopteroides* (SCHMALH.), *Phyllotheca* sp., *Callipteris murenensis* ZALESSKY, *Samarioscus* sp., *Dicranophyllum lusitanicum* (HEER) in the Boukou-Mouren Steppe.

Jisu-Honguer Formation. Limestones prevail in the upper part (about 580 m.), sandstones and conglomerates in the lower part (120 m.). The limestones are either dark brown or grey in colour, but a considerable thickness is pinkish; cherty in certain beds and dolomitic in others. The cherty beds are especially rich in fossils. Fauna: *Hemiptychina himalayensis* (DAV.) var. *mongolica* GR., *H. morrisi* GR., *Notothyris simplex* var. *mongoliensis* GR., *N. berkeyi* GR., *N. nucleolus* (KUTORGA), *N. irregularis* GR., *Athyris timorensis* ROTHPLETZ var. *mongoliensis* GR., *A. royssii* LÉVEILLÉ, *A. excavata* GR., *Dielasma acutangulum* WAAGEN var. *minor* GR., *D. jisuense* GR., *D. millepunctatum* HALLE var. *mongolica* GR., *D. truncatum* WAAGEN var. *mongolica* GR., *D. giganteum* TSCHERNYS. var. *anteplicata* GR., *D. itaitubense* (DERBY), *D. elongatum* SCHLOTH. var. *orientalis* GR., *Camarophoria mutabilis* TSCHERNYS., *C. superstes* (VERNEUIL), *C. purdoniformis* GR., *Hustedia grandicosta* (DAV.), *H. remota* (EICHWALD), *Martinia mongolica* GR., *M. orbicularis* GEMM., *M. rectangularis* GR., *M. distefanoi* var. *spissa* GR., *M. osborni* GR., *M. sinensis*

PERMIAN

Gr., *Uncinulus mongolicus* Gr., *Orthotichia derbyi* (Waagen) var. *nana* Gr., *Beecheria sublævis* (Waagen), *Morrisina sparsiplicata* (Waagen), *Squamularia elegantuloides* Gr., *S. indica* (Waagen), *S. waageni* (Loczy), *Enteletes andrewsi* Gr., *E. angulatoplicata* Gr., *E. obesa* Gr., *E. nucleola* Gr., *E. subobesa* Gr., *Meekella uralica* Tschernys., *Spirigerella salteri* Tschernys. (several varieties), *S. persaranæ* Gr., *S. rajah* (Salter), *S. saranæ* (Verneuil), *S. keilhaviiformis* Fredericks, *S. keilhavii* (Buch), *Spirifer moosakhailensis* Dav., *Spiriferina mongolica* Gr., *Productus* (*Echinoconcha*) *fasciatus* Kutorga, *P.* (*Waagenoconcha*) *humboldti* d'Orbigny, *P.* (*Linoproductus*) *lineatus* Waagen, *P.* (*L.*?) *mammatus* Keys., *P.* (*Striatifera*) *compressus* Waagen var. *corniformis* Chao, *P.* (*Juresania*) cf. *juresanensis* Tschernys., *P.* (*Striatifera*) cf. *ischmensis* Tschernys., *P.* cf. *porrectus* Kutorga, *Marginifera jisuensis* Chao, *M. typica* Waagen var. *septentrionalis* Tschernys., *M. gobiensis* Chao, *M. morrisi* Chao, *Aulosteges gigantiformis* Gr., *A. grangeri* Gr., *Derbyella bureri* Gr., *D. minor* Gr., *Derbya* cf. *hemisphærica* Waagen, *Streptorhynchus kayseri* Schellw., *S. pelargonatus* (Schloth.), *S. broilii* Gr., *Schellwienella regina* Gr., *Orthotetina* cf. *eusarkas* (Abich), *O. ruber* (Frech) (?), *Lyttonia nobilis* Waagen, *Oldhamina lopingensis* Gr. (?), *Richthofenia laurenciana* Waagen, *Euchondria* (?) *englehardti* (Etheridge and Dun), *Schizodus elongatus* Gr., *Pseudomonotis* (*Aviculomonotis*) *matthewi* Gr., *P.* (*A.*) *mongoliensis* Gr., *P.* (*A.*) *kasanensis* (Verneuil), *P. furcoplicatus* Gr., *P.* cf. *auriculatum* Gr., *Conocardium jisuensis* Gr., *Myalina* cf. *verneuili* (McCoy), *Myalina falcata* Gr., *Deltopecten* cf. *subquinquelineatus* (McCoy), *Bellerophon jonesianus* de Koninck, *B. squamata* Waagen var. *mongoliensis* Gr., *Luciella*, *Worthenia*, *Euomphalus*, *Naticopsis khoovensis* Waagen, *Strophosaltylus indicus* (Waagen), *Macrochilina* (*Sphærodoma*) *avellanoides* (de Kon.), *Soleniscus mongolicus* Gr., *Waagenophyllum virgalense* (Waagen and Wentzel) var. *mongoliensis* Gr., *Polycœlia longiseptata* Gr., *Geinitzella columnaris* (Schloth.) var. *tuberosa-sparsigeminata* Gr. This formation is typically exposed to the south-east of Sair Usu, where it reaches several thousand feet in thickness and forms a complex syncline.

Fusulina Limestone. Isolated exposures of a dark limestone with *Bradyina nautiliformis* Möller, *Fusulinella bocki* Möller, *Fusulina teilhardi* Lee, *F. konnoi* Ozawa, and *F. quasicylindrica* var. *brevis* Lee have been observed in the south-eastern part of Mongolia. The type-locality is situated at about 200 km. north of Kalgan. The limestone is not of great thickness. Age: Middle Carboniferous.

L. CARBONIFEROUS

Sair-Usu Series. Slaty and shaly strata with layers of conglomerate and limestones, typically exposed near Sair Usu (lat. 44° 43′ N., long. 107° 30′ to 108° E.). The limestones contain, among other Lower Carboniferous forms, *Michelinia* cf. *favosa*, *Cladochonus* sp., *Schizophoria resupinata*, *Rhipidomella* cf. *michelini*, *Spirifer* cf. *trigonalis* and *Gigantella* of the type of *G. giganteus*.

Khangai Series. Greywacke sandstones interbedded with shales or slates which latter are in places associated with siliceous limestone, often invaded by granite. The whole series probably amounts to 6,000 or 7,000 m. in thickness. Extensively exposed in the Gobi region. Probably largely Sinian, but possibly including Palæozoic sediments.

Wutai Formation. Greenish chlorite-schists as exposed in the Artsa Bogdo Range of the Altai Mountains, greenstones and chloritic phyllites in the mountains east of Ardyn Obo, and certain mica-schists and mica-phyllites associated with crystalline limestone exposed to the north of Pangkiang are classified as the Wutai Formation.

Archæan. Largely gneisses associated with schists and marbles, often penetrated and impregnated by igneous material. Typically exposed in the block mountains south and south-west of Tsetsenwan (about lat. 45° 30′ N., long. 104° 20′ E.).

(2) North Manchuria

Yellow loam, often sandy.

Hochiakou Clay. Black, sandy clay with lenses of sand and patches of kaolin, underlain by a fine-textured compact clay of green or brownish colour. The black sandy clay contains *Planorbis* and mammalian bones belonging to *Canis, Nyctereutes, Hyæna spelæa, Siphneus fontanieri* M. Edw. (and other living rodents), *Rhinoceros tichorhinus, Equus* cf. *przewalskyi, E. hemionus, Sus* sp., *Camelus knoblochi* Brandt, *Cervus* (*Euryceros*) *ordosianus* Young, *C. elaphus, Gazella przewalskyi* Buchner, *Spiroceras kiakhtensis* Pavlow, *Bubalus wansjocki* Boule and Teilh., *Bos primigenius* Boj., *Elephas nomadicus, E. primigenius,* and *Bison* sp.

Loams and Gravels of Uncertain Stratigraphical Relation. The gravels, often rather coarse, are sometimes associated with false-bedded sands and clays attaining, in places, a thickness of more than 25 m. There appear to exist two gravels, a High gravel and a Low gravel; the former stands at 78 m. and the latter 20 m. above the present river bed.

Basalt. Lava flows sometimes underlain by conglomerate with pebbles of gneiss and rhyolite. Thickness 50 m.

Red Sandstone. Reddish brown sandstone, loosely cemented and occasionally current-bedded, intercalated with beds of sand and inconsistent layers of gravel of medium grade. Sheets of basalt are locally embedded (intruded?) in this formation. Thickness probably exceeding 500 m. Early Tertiary or Upper Cretaceous.

CRETACEOUS

Kanho Formation. Upper part, almost entirely volcanic in origin, consisting of dark-coloured, vesicular andesite, porphyritic trachyte with phenocrysts of sanidine, fluidal rhyolite, tuff and volcanic breccia; thickness 365 m. Lower part, grey to greenish-grey sandstone and grey to dark-grey shale with occasional coal-seams and ill-preserved plants referred to *Cephalotaxopsis, Zamites, Czekanowskia;* thickness 250 m.

Nengkiang Formation. Dark or bluish grey shales, uniformly fine in texture, locally calcareous in certain horizons. The calcareous facies yields *Estheria* cf. *middendorfi* JONES. Fragments of *Cephalotaxopsis* occur in the shale. Thickness about 500 m.

JURASSIC

Muleng Series. Essentially sandstones with some intercalated shales. Coal-seams occur in the middle part and tuff in the lower part. Flora: *Cladophlebis browniana, C. denticulata, Ruffordia goepperti, Coniopteris* sp., *Plagiophyllum* sp., *Elatocladus sudzamoides, Pityophyllum nordenskioldi, Ginkgo* sp., *Neocalamites carreri.* Thickness about 200 m. Only developed in the eastern part of North Manchuria, where it is overlain by conglomerates and arkose sandstone.

Pamientung Slates. Highly metamorphosed micaceous slates and schists with beds of white marble, often injected by granite; believed to be of Upper Palæozoic age; exposed in the eastern part of the area.

Samachieh Quartzite. Hard quartzite, greyish-white or reddish-grey in colour, compact in texture. Thickness about 200 m. Probably Sinian.

Archæan. Light-coloured or brownish gneiss, banded structure not often developed; frequently invaded by granite and cut by quartz or fluorite veins.

(3) SOUTH MANCHURIA

Alluvium and other superficial deposits. Loess only present on the foothills of the Great Khingan, west of the Liaoho Valley.

Fushun Series. Shales of considerable thickness (700-800 m.) form the upper part of the series. This is followed by the main coal-bearing series consisting of shales with thick seams of bituminous coal. The main seam attains a maximum thickness of 60 m. The lower coal-bearing series consists of tuffaceous sandstone, conglomerate and shale in which are found two seams of coal. Sheets of basalt often appear between the main and the lower coal-bearing series, the latter being sometimes disturbed or baked by the basaltic flows, while the main coal-bearing series is intact. Flora: *Lygodium kaulfussi* HEER, *?Dryopterites, Osmunda lignitum* (GIEBEL) STUR., *Sequoia langsdorfii* (BRONGN.) HEER, *S.* cf. *disticha* HEER, *Glyptostrobus europaeus* (Brongn.) Ung., *G. ungeri* Palibin, *Populus glandulifera* Heer, cf. *Carpinus grandis* Ung., *Alnus kefersteinii* Ung., *Dryophyllum dewalquei* Sap. and Mar., *Fagus feroniæ* Ung., *Thuya* cf. *borealis* Heer, *Parrotia* cf. *priestina* Ett., *Quercus* sp., *Salix* sp., *Styrax* sp., *Aphananthe* sp., cf. *Zelkova ungeri* Kovats, cf. *Panax longissimum* Ung., cf. *Viburnum nordenskioldi* Heer, *Ginkgo*. These plants, though ranging from Upper Cretaceous to Pliocene, are believed to represent Oligocene.

Tuffaceous sandstones and shales followed downward by red and green tuffs and porphyritic lava in the eastern part of the Fushun coalfield. In the Pataohao coalfield, close to the Great Khingan, the red and green tuffs are intercalated with sandstones, shales, lava flows and thin seams of coal, having a total thickness of 100-200 m. This is followed by tuffaceous conglomerates becoming coarser towards the base. In the basal part occurs some yellowish-green tuff alternating with red and green clays and soft sandstones. Higher up, the soft sandstones intercalated in the conglomerate become red in colour. Thickness of this series 1,600-1,700 m.

Cretaceous

Heishan Series. Upper part, mainly clay-shales and soft, argillaceous sandstones with some conglomerate and a few thin seams of coal; about 200 m. thick. Middle part, a complex series of grey sandstones, black shales, greenish or yellowish clay and conglomerates with important seams of coal; thickness about 220 m. Lower part, clay-shales, sandstones and conglomerates without coal, shales and sandstones being more prevalent towards the base; a little over 100 m. thick. The coal-bearing beds carry, besides *Corbicula anderssoni* Gr., numerous plants, such as *Dioonites kotoi* Yokoyama, *Ginkgo digitata* Brongn., *Phœnicopsis speciosa* Heer, *Pityophyllum nordenskioldi* (Heer) Nath., *Podozamites, Czekanowskia, Nageiopsis, Taxodium* and *Sequoia* (?), in the Pataohao coalfield, on the western side of the Liaoho Valley; in the Sihan coalfield, to the east of the Liaoho Valley, a similar coal-bearing formation yields *Podozamites lanceolatus* (Lind. and Hutt.), *Coniopteris* sp., *Dioonites* sp., *Pinus* (*Pityophyllum* ?) *nordenskioldi* Heer, *Baiera gracilis* Bunb., and *Ginkgo lepida* Heer. The Sihan formation only attains a thickness of about 200 m.

Jurassic

Tiensufu Series. Upper part, mainly conglomerate with pebbles of quartzite, locally intercalated with quartzose sandstone; about 50 m. thick. Middle part, green and grey to black shales with thin-bedded sandstones and coal-seams yielding *Cladophlebis nebbensis* (Brongn.), *Palissya manchurica* Yokoyama, *Czekanowskia rigida* Heer, *C. murrayana* (L. and H.), *Coniopteris hymenophylloides* (Brongn.), *Schizoneura hoerensis* Hisinger, *Phyllotheca* cf. *sibirica* Heer, *Todites williamsoni* (Brongn.), *Ctenis kaneharai* Yok., *Dioonites brongniarti* (Mantell) [= *D. kotoi* Yok.], *Ginkgo lepida* Heer, and *Baiera gracilis* Bunb.; about 200 m. thick. Lower part, conglomerate, 100 m. thick. In places this series is capped by basaltic and trachy-andesitic flows which are often thoroughly weathered.

Triassic (?) Red Series. Mainly soft shale intercalated with sandstones, both dark-red in colour, with some yellowish and greenish beds in the basal part in which occurs a conglomerate. Thickness about 500 m. Well developed in the Penchihu coalfield.

PERMIAN

Millstone Formation. White, quartzose sandstone, often used for the manufacture of millstones, with some yellow and purplish shales in the basal part. Thickness about 250 m.

Shansi Series. Interbedded shales and sandstones, usually grey to black, but sometimes green or yellow in colour, containing numerous coal-seams and abundant plant remains. The leading species are: *Pecopteris arborescens* SCHLOTH., *P.* cf. *densifolia* (GOEPP.), *P. hemiteloides* BRONGN., *Callipteridium orientale* SCHENK, *C. trigonum* FRANKE, *Tæniopteris multinervis* WEISS, *Annularia stellata* (SCHLOTH.), *Sphenophyllum oblongifolium* UNG., *S. verticillatum* SCHLOTH., *Lepidodendron oculus-felis* ABBADO and ZEILL., *L.* aff. *gaudryi* RENAULT, *Lepidophyllum hastatum* LESQX., *Cordaites principalis* GERM., *Pachytesta?, Stigmaria ficoides* (STERNB.) and *Neuropteris flexuosa* (BRONGN.). The last-named species probably belongs to the Penchi Series. Thickness 170 m.

URALIAN

Taiyuan Series. Interbedded shales and sandstones, usually dark-grey in colour, occasionally greenish or yellowish, with several coal-seams and 6 or 7 beds of limestone which are generally charged with flint nodules. Fauna: *Boultonia willsi* LEE, *Pseudofusulina ? nobilis* (LEE), *Parafusulina richthofeni* (SCHWAGER), *Schwagerina moungthensis* DEPRAT, *Productus manchuricus* CHAO, *P. taiyuanfuensis* GR., *Marginifera pusilla* SCHELLW., *Spirifer taiyuanensis* CHAO, *Martinia manchuriensis* CHAO, *Aviculopecten manchuricus* CHAO. Thickness 86 m. in the Wuhutsui section.

M. CARBONIFEROUS

Penchi Series. Yellow and sometimes greenish sandstones intercalated with shales and 3 beds of limestone. The uppermost limestone, named the Penchi Limestone, attains a thickness of 5.5 m. in the type locality, namely, Penchihu. These limestones contain *Fusiella rawi* LEE, *Staffella sphæroidea* (MÖLLER), *Fusulinella bocki* MÖLLER, *Fusulina konnoi* (OZAWA), *F. pankouensis* (LEE), *F. cylindrica* FISCHER, *F. quasicylindrica* (LEE), *F. schellwieni* (STAFF), *Chætetes* sp., *Multithecopora penchiensis* YOH, *Alveolites tangshanense* GR., *Lithostrotion kaipingense* GR., and *Choristites* cf. *mosquensis* FISCHER. Thickness 90 m.

ORDOVICIAN

Actinoceras Limestone. Massive, grey or reddish-grey limestone which has yielded the type specimen of *Actinoceras richthofeni* FRECH from near Mukden. The term Ssuyen Formation has been recently applied to this limestone, and is subdivided into two palæontological zones: the upper zone is characterized by *Archæocyathus manchuriensis*, and the lower zone by *Lambeoceras nanum*. Other fossils found in this formation are: *Cycloceras* (?) *peitoutzense* GR., *Stereo-*

ORDOVICIAN

plasmoceras pseudoseptatum GR., *S. submarginale* KOBAYASHI, *S. subcentrale* KOBAY., *Tofangoceras pauciannulatum* KOBAY., *T. irregulare* KOBAY., *Actinoceras tani* GR., *A. coulingi* GR., *A. manchuriense* KOBAY., *A. submarginale* GR., *A. nanum* GR., *A. harioi* KOBAY., *A. suanpanoides* GR., *A. curvatum* GR., *A. murakamii* KOBAY., *Cyrtactinoceras mitsuishii* KOBAY., *Discoactinoceras multiplexum* KOBAY. and *Cyrtoceras* (*Meloceras*) aff. *asiaticum* YABE.

Wuting and Kangyao Formations. Essentially limestones characterized by "Eozoon reefs" in the basal part containing characteristic Lower Ordovician fossils. The whole of the Ordovician formation amounts to no less than 700 or 800 m.

CAMBRIAN

Fengshan Formation. Argillaceous limestones and shales with intraformational conglomerate, subdivided into two zones: upper, *Dictyella* zone, and lower, *Tsinania* zone.

Changshan Formation. Thin-bedded limestones and shales with wurmkalk or limestone conglomerates, subdivided into two zones: upper, *Kaolishania* zone, and lower, *Chuangia* zone.

Fuchou or Lungmonn Series. Upper part, greenish grits and earthy sandstones intercalated with numerous thin layers of shale; middle part, interbedded shales and limestones, sometimes oolitic, mostly grey or green in colour, but occasionally buff or purplish; lower part, mainly soft greenish shale with a few differently coloured bands. Total thickness 170 m.

Yungning Sandstone. Largely cross-bedded, earthy and felspathic sandstone of dark-red colour with local shales and conglomerates; the latter attain some importance towards the base. The shaly facies has yielded *Redlichia.* Thickness 600 m.

Sinian Formation. Siliceous limestones and slates above and quartzites below, thickness considerable.

Archæan Gneiss and Granite.

(4) SOUTHERN KHINGAN AND JEHOL

Loess. Primary loess widespread in Jehol, reworked sandy loess with gravels and "moraine-like" boulder bed in the Weichang area gradually thinning out towards the east. *Rhinoceros tichorhinus* often present among other mammalian remains. *Limnæa, Pupa,* and *Struthiolithus* eggs also occur. Maximum thickness 60 m.

Red Loams and Gravels. Homogeneous red loam in the upper part, intercalated with clays containing pebbles and boulders in the lower part. The lower beds are sometimes yellowish in colour and rarely white or black. Sandy gravels are also occasionally present. Thickness 20-33 m.

Weichang Basalt. Uniform basalt with tuffaceous material at the base. Rarely contains "pegmatitoid" layers. Thickness 75 m. Intercalated in the basal part are sometimes found fine sands and silts in which occur *Pinus, Carpinus, Betula, Castonea, Ulmus, Zelkova* and *Diospyras*, probably belonging to the Upper Miocene according to Depage. Widespread to the north-west of Weichang.

CRETACEOUS

Chaoyang Series. Mainly tuff, rhyolitic lava and tuffaceous conglomerate, with beds of yellowish and greenish sandstones and black shales containing seams of coal which attain workable thickness in one locality, but disappear in the next. The lithological character of this series varies widely over the whole area. Plant remains resembling *Chondrites patulus* and *Algites furcatus* are reported to occur in a light greenish-grey shale. Thickness over 1,000 m.

Chihfeng Series. Shales, sandstones, mainly buff, green and grey in colour, usually rather fine in texture, containing coal-seams. Facies-variation pronounced. A white marl appears, however, to persist over a wide area. *Lycoptera jeholensis* Gr. often abounds in this horizon, being associated with *Estheria* and *Corbicula jeholensis* Gr. From a calcareous shale *Compeloma clavilithiformis* Gr., *C. fengtienensis* Gr., *C. yihsienensis* Gr., *C. tani* Gr. and, from a grey clay-shale, *Corbicula anderssoni* Gr., *Ancylus teilhardi* Ping have been collected. Plant remains referable to *Pityophyllum* and insects belonging to *Samarura* have been also found. Thickness widely variable, 200-900 m.

JURASSIC

Peipiao Series. Sandstones, shales and clays intercalated with conglomerates which become coarser towards the lower part. Important coal-seams also occur in the lower part. *Baiera* and *Zamites* are found in different horizons throughout the formation. Thickness about 800 m.

Hsinlungkou Series. Andesitic tuff and tuff-conglomerates, especially well-developed in the Hsinlungkou district, north-east of Chaoyang and south-west of Peipiao. Thickness 360-500 m.

Red Sandstone. Fine-grained red sandstone, generally thin-bedded, occasionally interstratified with pale green sandstones. Age uncertain.

PERMIAN

Tayaokou Conglomerate. Conglomerate in the upper part, composed of large pebbles and a quartzose matrix of pale red colour; coarse, yellow sandstone with beds of conglomerate in the lower part. About 200 m.

Hunglohsien Series. Brownish sandstone in the upper part, buff, grey and black shale and coal-seams in the lower part, the latter being occasionally intercalated with sandstones and conglomerates. A white, quartzose conglomerate is sometimes present in the base. *Neuropteris, Sphenophyllum* and *Cladophlebis* occur in the shales. Thickness about 300 m.

Lingsi Slates of the Khingan proper probably comprise a part or the whole of these formations.

Cambro-Ordovician limestones are only present in a few localities. The Cambrian is represented by wurmkalk and red shale, and the Ordovician by a pure, light grey limestone used for lime-burning.

Sinian Formation. Upper part, grey to whitish-grey limestone often containing nodules or bands of flint, intercalated, in places, with grey and pale green shales; about 500 m. thick. Lower part, white to whitish-grey quartzite, usually fine-grained and thick-bedded, but sometimes thinly stratified with coarse grains of quartz; about 300 m. thick.

Archæan. Granitoid gneiss often penetrated by pegmatites and auriferous quartz-veins.

(5) INSHAN RANGE

Malan Loess. Yellowish grey loess, primary or redeposited, with intercalations of gravels, particularly frequent in the basal part. Thickness 0-10 m.

Gravels. Gravels of different grades, some fairly coarse with pebbles or blocks of rock up to 1 foot across, others fine, interbedded with sandy layers. Thickness 10-50 m.

Anpei Sand. Fine sand, usually yellowish grey in colour, with occasional layers of gravel. In places the sands are largely replaced by yellowish and whitish-grey clay. Thickness up to 40 m.

Lacustrine Clays. Fairly homogeneous clays, usually red, but sometimes yellowish or greenish grey in colour, with scattered pebbles or layers of sand and gravel. These clays do not necessarily belong to one stage.

Hanoorpa Basalt. Plateau basalt rather rich in olivine varying in composition and structure. Porphyritic with phenocrysts of felspar, olivine, augite, magnetite in certain facies, glassy in others. Generally dense in the lower part and vesicular or even drusy in the upper part. In the drusy cavities which are sometimes as large as a fist, crystals of quartz, beryl, agate often occur either in radial arrangement or embedded in a clayey matrix. Thin layers of yellowish, crumbly shale containing lignite are sometimes intercalated in the basalt or immediately underlying it. They carry plant remains, including *Pinus, Comptonia anderssoni* FLORIN, *Carpinus* and *Phyllites*. Thickness 190-200 m. Only developed in the eastern part of the range. Age: Mid-Tertiary.

CRETACEOUS

Tumulu Series. Upper part, pale red and greenish-grey clays; lower part, coarse and fine conglomerates interbedded with cross-bedded fine sandy layers. Thickness about 500 m. at the maximum.

Nantienmen Formation. Coarse and fine conglomerates alternating with fine, current-bedded sandy layers which are usually sharply

CRETACEOUS

defined. The pebbles are largely derived from the underlying porphyries. Fine-grained shales, muds and coal-bearing shales occur at the base. Thickness over 800 m. Typically developed in the Kalgan area. Possibly partially equivalent to the Tumulu Series.

Kalgan Series. Acid lavas and porphyries ranging from vitrophyres and quartz-porphyries to trachyte and augite-andesite. Intercalated with these are conglomerates and tuffs similar in composition to the lavas and porphyries. The lavas are often vesicular or amygdaloidal, the cavities being filled with crystals of quartz, zeolites, carbonates and chalcedony or agate exemplifying lithophysæ in the coarser variety. Thickness about 700 m. Well-developed in the Kalgan area, but absent in the western part of the Inshan Range.

JURASSIC

Tachingshan Series. Green, red and sometimes dark grey shales, sandstones and conglomerates. In places sandstones predominate. Thickness 500-600 m.

Shihkuai Series. Greenish or light grey sandstones, sometimes slightly conglomeratic, usually containing some shales and occasionally a few beds of limestone. Three to 10 seams of coal occur in this formation. A thick conglomerate is sometimes present at the top. Plant remains : *Asplenium whitbyensis* BRONGN., *A. argutulum* HEER, *Anomozamites schmidti* HEER, *Pterophyllum richthofeni* SCHENK, *P. æquale* BRONGN., *Podozamites lanceolatus* HEER, *P. gramineus* HEER, *Elatides chinensis* SCHENK, *Cladophlebis denticulatus* BRONGN., *Todites williamsoni* BRONGN., *Czekanowskia rigida* HEER, *Coniopteris, Thyrsopteris.* Thickness 300-500 m.

PERMIAN

Sarachi Series. Conglomerates with sandstones alternating with shales mostly red in colour. Thickness 500-600 m.

Hsuanmachuang Series. Shales, quartzose sandstones with several seams of coal and some conglomerates. In the western part of the range, this series is often altered to phyllites, quartzites and graphite. Fossils : *Sphenophyllum oblongifolium* UNG., *S. thoni* MAHR, *S. emarginatum* BRONGN., *S.* cf. *majus* BRONGN., *Neuropteris pseudovata* GOTHAN and SZE, *N.* cf. *acutifolia* STERNB., *Annularia pseudostellata* POTONIÉ, *Pecopteris arborescens* GOEPP., *P. unita* BRONGN., *P.* cf. *feminæformis* SCHLOTH., *Lepidodendron, Calamites, Odontopteris, Sphenopteris, Cordaites borassifolius* STERNB., *Walchia?* Thickness 100-160 m.

SINIAN

Shihnakan Limestone. Well-bedded, dark grey limestone, generally earthy in composition, becoming somewhat thick-bedded and more argillaceous towards the basal part. Almost free of flint in most cases, sometimes intercalated with shales, partly metamorphosed. Thickness about 600 m. Only found in the western part of the range.

Nankou Limestone. White or grey limestone, often highly siliceous with numerous nodules of flint, quartzite and dark purplish slate prevail in the basal part. Thickness 130-300 m.

Kuyang Formation. Mica-schists, phyllites, greywackes, quartzites, marbles or crystalline limestones all occurring in highly disturbed state.

Archæan Gneiss. Probably belonging to the Sangkan System.

(6) North-Eastern Hopei

Loess with basal gravels in which occur bones of *Elephas nomadicus*. Thickness about 30 m. on the average.

Fissure deposit with *Siphneus tingi* Young in the higher horizons, and *Prosiphneus intermedius* Teilhard and Young in the lower.

Soft red sandstone, thin-bedded, attaining a considerable thickness, probably belonging to the Triassic.

Permian

Kuyeh Formation. Sandstones and variegated clays with a thick millstone in the lower part and a thin conglomerate at the base. *Phyllotheca, Thinnfeldia* and *Pecopteris* are reported to occur in these beds. Thickness 30-50 m.

Tangchiachwang and **Chaokochwang Formations.** Sandstones and shales with sandstones prevailing in the upper and middle parts, and shales in the lower part. The top of this formation is marked by a bed of hard, reddish clay-stone. The lower boundary is not sharply defined, but on the evidence of the flora it is believed that the boundary should be drawn not far below the 13th coal-seam counting from the top of the entire coal-bearing series in the Kaiping Basin. Coal-seams and plant-bearing beds occur at different horizons. The leading floral elements are: *Stigmaria ficoides* Brongn., *Sphenophyllum thoni* var. *minor* Sterzel, *S. oblongifolium* Germar, *S. emarginatum* Brongn., *S. costæ* Sterzel, *Neuropteris pseudovata* Gothan and Sze, *Pecopteris ellgeri* Günther, *P. arborescens* Schloth., *Cordaites principalis* Germar, *C. schenkii* Halle, *Annularia stellata* (Schloth.) Wood, *Lepidodendron kaipingensis* Günther, *Lepidophyllum* cf. *minus* Schenk, *Emplectopteris triangularis* Halle, *Caulopteris manchuriensis* Hatae, *Alethopteris* aff. *costei* Zeiller, *Selaginellites elongatus* Gothan and Günther, *Cyclopteris* sp., *Tæniopteris* sp. and *Gigantopteris nicotianæfolia* Schenk. Thickness 250 m.

Uralian

Taiyuan Series. Sandstones, shales and coal-seams with local conglomerates and a thin bed of calcareous shale which contains *Productus taiyuanfuensis* Gr., *P. chonetoides* Chao, *Marginifera pusilla* Schellw., *M. orientalis* Chao, *Chonetes carbonifera* Keyserling, *C. latesinuata* Schellw., *Derbyia* and *Phillipsia.* A plant-bearing shale crowded with *Lepidodendron oculus-felis* Abbado and Zeiller marks a characteristic horizon in the upper part of the formation. Thickness about 75 m.

MIDDLE CARBONIFEROUS

Penchi Series. Alternating beds of shales, sandstones and clays with a few coal-seams of no economic value. A marine limestone, named the Tangshan Limestone, 2 m. thick, caps the series, and a thick bed of hard, bluish clay of pisolitic structure lies at the bottom. The Tangshan Limestone yields *Bradyina nautiliformis* MÖLLER, *Staffella sphæroidea* (MÖLLER), *Fusulinella bocki* MÖLLER, *Fusulina cylindrica* FISCHER, *F. konnoi* (OZAWA), *Multithecopora penchiensis* YOH, *Chætetes tangshanense* CHU, *Lithostrotion kaipingense* GR., *Orionastrea* sp., *Caninia* sp., *Choristites mosquensis* FISCHER, *Spirifer* (*Tangshanella*) *kaipingensis* CHAO, *S.* (*Brachythyrina*) *strangwaysi* VERNEUIL, *Productus gratiosus* var. *occidentalis* SCHELLW., *Phillipsia* sp. and *Sinocrinus* sp. Besides numerous Moscovian foraminifera and other faunal elements of the same age found in the Tangshan Limestone, Westphalian as well as long-ranged floral elements are found in the shales below that limestone. The leading forms are: *Neuropteris kaipingiana* GOTHAN and SZE (belonging to the group of *N. gigantea*), *Conchophyllum richthofeni* SCHENK, *Potoniea adiantiformis* ZEILLER, *Lepidophyllum minus* SCHENK, and *Cordaites principalis* GERMAR. *Sphenopteris*, *Lepidodendron*, *Annularia*, and *Calamites* are also represented. Thickness 80 m.

ORDOVICIAN

Machiakou Limestone. Massive, grey limestone with occasional flints, fossiliferous at two horizons in the upper part. The leading forms are: *Orthis calligramma* DALM. var. *orthambonites* VON BUCH, *Strophomena* cf. *incurvata* SHEPARD, *Ctenodonta symmetrica* GR., *Eccyliomphalus tangshanense* GR., *Lophospira morrisi* GR., *L. pulchelliformis* GR., *L. trochiformis* GR., *L. acuta* GR., *L. gerardi* GR., *L. terrassa* GR., *L. obscura* GR., *Pagodispira derwiduii* GR., *P. dorothea* GR., *Liospira barbouri* GR., *Salpingostoma terrilli* GR., *Vaginoceras tsinanense* GR., *Cycloceras?* *peitoutzeense* GR., *Stereoplasmoceras pseudoseptatum* GR., *S. machiakouense* GR., *S. actinoceriforme* GR., *Actinoceras richthofeni* FRECH, *A. tani* GR., *A. nanum* GR., *Cyrtactinoceras frechi* GR., and *Asaphus* cf. *bochmi* LORENZ. Thickness about 400 m.

Liangchiashan Limestone with *Ophileta plana* GR., *Hormotoma loquieri* GR., *Cameroceras styliforme* GR., *Piloceras platyventrum* GR. Thickness 275 m.

Peilintze Limestone with *Archæoscyphia chihliensis* GR., *Ophileta squamosa* GR., *Proterocameroceras mathieui* GR., *Chihlioceras nathani* GR., *C. chingwangtaoense* GR., *Piloceras platyventrum* GR. Visible thickness 100 m.

Yehli Formation. Earthy limestone and shales, often concretionary in the lower part with a persistent but rather thin conglomerate at the base. The upper part yields *Dichograptus separatus* var. *hopeiensis* SUN, *Desmograptus yehliensis* SUN, *Loganograptus logani* var. *kaipingensis* SUN, *Didymograptus fearnsidesi* SUN, *D. nitidus* (HALL) and *Dendrograptus* cf. *grabaui* SUN. The lower part contains *Dictyo-*

ORDOVICIAN

nema flabelliforme var. *orientalis* SUN, *Callograptus bulmani* SUN, *Dendrograptus irregularis* SUN, *D. grabaui* SUN and *Acanthograptus kaoi* SUN. Besides these, *Ophileta, Orthis, Orthoceras* and *Suecoceras* occur in this formation. Typically developed in the Kaiping Basin, and probably equivalent, at least in part, to the Peilintze formation of the Liukiang coalfield. Thickness about 300 m.

CAMBRIAN

Fengshan Limestone. Thin-bedded limestone intercalated with purple and greenish shales, the latter being often of a calcareous nature. Fossils: *Quadraticephalus linyuensis* SUN, *Saukia acamus* (WALCOTT), *Calvinella? yini* SUN, *Ptychaspis? fengshanensis* SUN, *Mansuyia orientalis* SUN, *Illænurus* sp., *Obolus luanhsienensis* GR., *Lingulella kayseri* GR.

Changshan Formation. Mainly purple shale with numerous thin bands of wurmkalk and shaly limestone containing *Changshania equalis* SUN, *C. conica* SUN, *C. truncata* SUN, *Agnostus* cf. *pisiformis* LINN., *A. hoi* SUN, *Dikellocephalites flabelliformis* SUN, *Obolus mollisonensis?* WALCOTT and *Eoorthis* sp. Total thickness of the Fengshan and Changshan formations about 180 m.

Changhia Formation. Massive, oolitic limestone in the upper part, alternating with purple shales in the lower part; containing *Dorypyge richthofeni* DAMES, *Damesella blackwelderi* var. *minor* SUN, *Dolichometopus deois* WALCOTT, *Lisania rectangularis* SUN, *Anomocare flava* WALC., *Solenopleura nodosa* SUN, *Nisusia hayasakai* SUN and *Crepicephalus* sp. Thickness 150 m.

Manto Formation. Upper part, crumbly, micaceous shales of purplish colour now and then intercalated with greenish shales and sandstones; lower part, mainly red sandstone and sandy shale with thin beds of limestone. Fossils: *Acrothele cheni* SUN, *Lingulella manchuriensis?* SUN, *Obolus* sp., *Conokephalina gerardi* SUN, *C. kaipingensis* SUN, *Ptychoparia chenshanensis* SUN, *P. yohi* SUN, *P. fongi* SUN. Thickness 150 m.

Sinian Formation. Siliceous limestone with questionable algal remains (*Collenia?*) in the upper part merging downward into white and reddish quartzites, often false-bedded and ripple-marked. These are frequently intercalated with micaceous slates and slaty sandstones. In the middle part of this formation a massive conglomerate attains a thickness of 100 m., and in the basal part occurs a bed of iron ore of inferior grade, measuring some 20 m. thick, which is often traversed by numerous septaria. Total thickness about 2,500 m.

Wutai Formation?. Mica-schists and granite of unknown relation with the Sinian.

(7) Western Hills of Peking

Malan Loess.

Low Gravel. Often forming low-lying terraces along the present river courses.

Red Loam. Usually occurring on hill-sides in small patches. Sometimes it appears to merge into the "Low Gravel." The fissure-deposit of Choukoutien with a vast quantity of animal remains and the skulls of Peking Man is believed to have been largely formed during this stage. Hence the name Choukoutien Stage.

High Gravel. Gravels occurring on the flanks or on top of the hills near Peking standing some 80 m. higher than the present plain.

Changsintien Gravel. Rudely stratified gravels with well-rounded pebbles of many kinds, including agglomerate, rhyolite, andesite and Sinian limestone or quartzite, usually moderately coarse, occasionally boulders as large as half a metre across are present. In the upper and lower parts are intercalated layers of a purplish clay which has yielded the pelvis of a rodent and an upper premolar of ?*Eudinoceras*. Thickness about 100 m. Eocene or Oligocene.

CRETACEOUS

Hsiachuang Series. Purple shales, clays, yellow sandstones, conglomerates, marls and fossiliferous fresh-water limestones. The calcareous facies is particularly dominant in the lower part of the series. *Cyparisidium, Elatocladus* and *Pityophyllum* occur above the limestones, and *Podozamites lanceolatus* is also reported from the upper part of the series. Thickness about 200 m.

Lushangwen Series. Shales and sandstones of purple, green, yellow and grey colours with 5 or 6 layers of conglomerate intercalated at different horizons and with *Onychiopsis psilotoides* WARD near the base. Thickness 250-300 m.

Tuoli Conglomerate. Massive conglomerate, generally thick-bedded, with thin partings of grey and purple shale. The pebbles in the conglomerate are sub-rounded, largely consisting of rhyolite, trachyte and andesite. Quartzite and limestone are relatively rare. Thickness 500 m.

Hsinchuang Series. Conglomerates and sandstones abound in the upper part, sandy or clayey shales interbedded with conglomerate in the lower part. The pebbles in the conglomerates are almost exclusively composed of igneous rocks. Visible thickness 300 m.

Tiaochishan Formation. Andesite, porphyries, andesitic tuff, agglomerate, volcanic ash, tuffaceous conglomerate, lenses of anthracite with some shales at the top containing *Estheria, Podozamites, Nilssonia, Elatides,* and rhyolite flows and volcanic breccia in the lower part. Thickness 1,500 m.

CRETACEOUS

Chiulungshan Conglomerate. Coarse conglomerates with well-rounded pebbles often alternating with green sandstones which are sometimes tuffaceous in character. Sandy shales are usually present. Thickness 500-850 m.

JURASSIC

Mentoukou Formation. This coal-bearing formation is subdivided into three series. The upper or the Lungmen Series, consists of grey to black sandy shales with thin layers of sandstone, coal and local conglomerates. A fairly thick conglomerate occurs at the top, and another at the bottom; about 160 m. thick. The middle, or the Upper Yaopo Series, is largely composed of grey sandy shale and some sandstones with an arkose sandstone in the middle; over 108 m. in thickness. The lower, or the Lower Yaopo Series, consists of alternately bedded grey sandstone and black shale with numerous seams of coal. *Coniopteris burejensis* (ZAL.) SEWARD, *C. hymenophylloides* BRONGN., *C.* (*Thyrsopteris*) *murrayana* BRONGN., *Cladophlebis* (*Todites*) *whitbyensis* BRONGN., *Neocalamites* cf. *hoerensis* (SCHIMPER) HALLE, *Equisetites* cf. *lateralis* (PHILLIPS) MORRIS, *Hymenophyllites tenellus* NEWBERRY, *Podozamites lanceolatus* HEER, *Czekanowskia rigida* HEER, *Elatides cylindrica* SCHENK, *Thyrsopteris orientalis* SCHENK, *Dicksonia coriacea* SCHENK, *Baiera angustiloba* HEER, *Cladophlebis remota* HALLE, *Taxites spatulatus* NEWB., *Ginkgo flabellata* HEER, *Ctenozamites browniana* HALLE, *?Phœnicopsis speciosa* HEER and *Pityophyllum nordenskioldi* (HEER) Krystofovich are present among other Lower Jurassic plants. Total thickness 868 m.

PERMIAN

Shuangtsuan Series. Sandstones and shales, often purple or green in colour, but brownish or yellowish sandstones prevail in certain facies. In the middle part of the series a thin layer of coal is often met with. Basal conglomerate nearly always present. The coal-bearing shale or its equivalent horizon yields the following plants: *Psygmophyllum multipartitum* HALLE, *Pecopteris* (*Asterotheca*) *orientalis* SCHENK, *P. lativenosa* HALLE, *Neuropteridium coreanicum* KOIWAI, *Nephropsis* cf. *integerrima* (SCHMALHAUSEN), *Tæniopteris spatulata* (MCCLELLAND), *Nilssonia* cf. *simplex* OISHI, *Danæopsis hughesi?* FEISTM., *Lobatannularia heianensis* (KODAIRA), *Podozamites distans?* (PRESL.). In the Western Hills of Peking, this formation is sometimes entirely absent. When present, its thickness varies from 150 to 200 m.

Hungmiaoling Sandstone. Quartzose sandstones of dark colour, occasionally intercalated with purple shales. Thickness 150 m. or more.

STEPHANIAN

Yangchiatun Series. Greenish grey shales intercalated with buff sandstones in the upper part, and dark grey or black shales and coal-seams in the lower part. A bed of conglomerate usually present at the base. Plants including *Lepidodendron, Calamites* and *Annularia* occur in several horizons. A light-coloured shale near the base yields *Productus taiyuanfuensis* GR., *P. manchuricus* CHAO, *Conularia* sp. and other elements of the Taiyuan fauna. Thickness 130-200 m.

M. CARBON.

Penchi Formation. Represented by a severely deformed and crystalline limestone of no great thickness only in the Fangshanhsien district and containing *Chætetes*. Elsewhere in the Western Hills of Peking this formation is usually absent, and the Taiyuan Series rests immediately on an eroded and iron-stained surface of the Ordovician limestone.

ORDOVICIAN

Actinoceras Limestone. Massive, thick-bedded, dark blue limestone of dense and compact texture. Fossils occur in two horizons. The higher fossiliferous horizon which lies near the top of the formation yields *Actinoceras coulingi* GR. and *A. suanpanoides* GR., and the lower horizon which lies near the base, yields *Eccyliopterus kushanensis* GR., and *Stereoplasmoceras pseudoseptatum* GR. Thickness 300 m.

Peilintze Limestone. Massive, thick-bedded, dark limestone frequently intercalated with rows of nodular flints which are of lenticular or spheroidal shape, and are arranged nearly parallel to the bedding planes. Towards the lower part the limestone becomes shaly, and is often actually intercalated with dark-coloured shales. Fossils are usually found in the flinty layers. They are mainly distributed in two horizons, though scattered individuals occur throughout the formation. The upper part of the limestone contains *Chihlioceras nathani* GR., *Archæocyathus chihliense* GR., *Piloceras platyventrum* GR., *Proterocameroceras mathieui* GR., *Ophileta (?) squamosa* GR. and *Orthis* sp. More primitive forms occur near the base, such as *Proterocameroceras minor* (much more slender than *P. mathieui*) and *Chihlioceras* sp. (much smaller than *C. nathani*). Thickness 110 m.

CAMBRIAN

Wurmkalk Series. Thin-bedded, dark limestones, often shaly and conglomeratic with occasional beds of oolite in the lower part. Most of the limestone conglomerates exhibit the characteristic structure of wurmkalk. This series is sometimes named the **Taoyuan Formation.** It contains *Saukiella peipingensis* SUN, *Saukia?* sp. *Ptychaspis subglobosa* GR., *Tsinania ceres* (WALCOTT), *T. peipingensis* SUN and *T. acuta* SUN. Thickness 204 m.

Changhia Oolite. Coarse and medium-grained oolites intercalated with brownish and grey shales. Thickness 74 m.

Manto Shale. Green shales in the upper part and red shales in the lower; base not exposed.

Shamaling Shale. Black shale of carbonaceous nature, sometimes mistaken for coal measures. Thickness 170 m.

SINIAN

Nankou Limestone. Siliceous limestone dark or light-grey in colour and highly compact in texture with nodules and bands of flint. A white quartzite, some 52 m. thick, is intercalated in the basal part of this limestone. Peculiar, laminated bodies of cylindrical or conical shape, generally referred to *Collenia chinensis* GR. and TIEN, *C. cylin-*

SINIAN

drica GR. and TIEN, *C. angulata* and *C. circulata* GR. and TIEN, abound in the basal and the higher parts of this limestone. Thickness 115-1,000 m.

Huyutsun Quartzite. White quartzite, often false-bedded and sometimes ripple-marked, intercalated with purple shales and black slates. Thickness 220 m.

Wutai Formation. Gneisses and schists only locally exposed.

(8) EASTERN SHANTUNG

EOCENE?

Wangshih Series. Upper part, chiefly conglomerates usually loosely cemented. The pebbles are mostly subangular, consisting of quartzite, quartz, gneissic granite and occasionally andesite or trachy-andesite; thickness about 1,000 m. Middle part, mainly red clay intercalated with loose sandstones and conglomerates occasionally greenish in colour. From the greenish beds fragments of bones have been obtained belonging to Sauropods, Hadrosauria, Schildkrote, Theropods, *Helopus zdanskyi* WIMAN and *Tamus sinensis* WIMAN; thickness about 300 m. Lower part, sandstones and greenish shales yielding *Cyrena* (*Sphærium*) *tani* GR., *Cyrena* (*Pisidium*) *shantungensis* GR., *C.* (*P.*) *wangshihensis* GR., *C.* (*P.*) *retrorostra* GR., *C.* (*P.*) *altiformis* GR., *Limnæa* sp. and *Cyclophorus* sp.; thickness about 700 m.

CRETACEOUS

Chingshan Series. Upper part, largely tuffs, agglomerates with some intercalated clays; lower part, red clays intercalated with andesitic and trachytic flows and some tuff. Bones of Sauropods and a fresh-water shell, *Leptesthes chingshanense* GR., have been found in the basal beds. Thickness 1,200 m.

Laiyang Series. Upper part, largely fine shales yellowish in colour, becoming sandy towards the higher horizons; thickness about 400 m. Middle part, brownish grey to dark grey, papery shales, hardening like slate at intervals, more so towards the base; thickness 700 m. The slaty layers are often richly fossiliferous. Insects, fishes, crustacea and plants are especially abundant. Insects: *Laiyangia paradoxiformis* GR., *Sinoblatta laiyangensis* GR., *Proteroscarabæus yeni* GR., *Chironomoptera* (*Samarura*) *gregaria* PING, *C.* (*S.*) *malanura* PING, *Coptoclava longipoda* PING, *Mesolygæus layangensis* PING, *M. rotundocephalus* PING. Pisces: *Lycoptera sinensis* SMITH-WOODWARD, *L. ferox* GR. Phyllopod: *Estheria* cf. *middendorfi* R. JONES. Plants: *Brachyphyllum obsesum* HEER, *B. magnum* CHOW, *B. multiramosum* CHOW, *Sphenolepsis elegans* CHOW, *Pagiophyllum* sp., *Palæocyparis* cf. *flexuosa* SAP., *Auracarites* sp., *Baiera* cf. *australis* McCOY, *Zamites* sp., *Thinnfeldia* sp. Lower part, conglomerates alternating with buff, quartzitic sandstones; about 100 m. thick.

Wutai Formation. Greenish or dark-coloured hornblende-mica-schists alternating with marbles, frequently invaded by granites. Thickness 500 m.

Archæan Gneiss and Granite.

(9) WESTERN SHANTUNG

Loess with beds of more or less well consolidated gravel intercalated in the lower part.

Reddish Loam with calcareous concretions and with occasional basal gravel. Iron-manganese pisolites are often disseminated in the basal layer of the loam when it is in direct contact with the weathered and eroded surface of solid rocks, or are spread below the basal gravel when the latter is present.

Basalt. Distributed in the Taian, Ssushui and Feihsien districts.

Wenho Conglomerate or **Breccia.** Large and small fragments of rocks mixed in an earthy matrix showing rude stratification and intercalated with lenticular layers of sand. Thickness about 600 m. in the thickest part.

Kuanchuang Series. Upper part: sands or sandstones and clays, predominantly red, occasionally dark grey in colour, with some greenish marls, cream-coloured marly limestone and variegated clays. The fresh-water limestone and sandstone are here and there crowded with gastropods, and the greenish marls have yielded Rodentia, *?Pterodon*, Perissodactyla, Hyracotherinæ, *?Grangeria canina* ZDANSKY and *Cricetodon schaubi* ZDANSKY. Lower part: coarse and fine conglomerates alternating with red clay-loams which contain layers of calcareous concretions. Red sands are usually present. Total thickness 600-1,100 m. Eocene, possibly ranging to Oligocene.

CRETACEOUS

Mengyin Series. Upper part, greenish-grey, shaly sandstone with tuff-conglomerate and lava of andesitic composition and lenses of grey sandstone and violet mudstone; middle part, greenish and brownish shaly sandstone; lower part, hard green sandstone, coarse-grained. Fossils occur in different horizons. *Unio* (*Lampsilis*) *johan-böhmi* FRECH, *U.* cf. *menkii* DUNKER, *Mycetopus mengyinensis* GR., *Bithynia mengyinense* GR., *Valvata suturalis* GR., are among the fresh-water shells, and *Lycoptera* sp., *Sinamia zdanskyi* STENSIO, *Sinemys lens* WIMAN, *Sinochelys applanata* WIMAN, *Scutemys tecta* WIMAN, *Helopus zdanskyi* WIMAN and Stegosauria are among the vertebrates. Thickness 380-1,240 m.

JURASSIC

Santai Series. Variegated sandstone becoming conglomeratic towards the base, sometimes altered to quartzite through contact metamorphism. Thickness not less than 500 m. as developed in the western part of the Tzuchuan-Poshan coalfield.

Shangkunlun Series. Yellowish-green sandstones and shales, occasionally conglomeratic in the upper part. White, coarse sandstone and dark grey to black shales are usually present. The former is used for glass-making, and the latter appear to be associated with poor coal-seams. Ill-preserved plants have been obtained from this series, but none is determinable. Thickness 160 m.

Hsiakunlun Series. Mainly dark red sandstone, rather loose in texture, often cross-bedded, with a few intercalated conglomerates in places. The top and bottom beds are, in certain facies, replaced by shales of greenish, yellowish or brown colour. Thickness widely variable, ranging from a few tens of metres to 700 m. Probably Triassic.

Millstone Formation. Massive quartzose sandstone extensively used for the manufacture of millstones, attaining considerable thickness in the northern and southern parts of the area, but absent in the central part.

PERMIAN

Takueishan Series. Interbedded shales and sandstones of greenish-yellow colour with sandstones prevailing in the uppermost part, and bauxite-bearing shales in several horizons. Where the bauxite is enriched the shales usually show an oolitic structure. These shales are sometimes associated with porcelain-clay of superior quality. Thickness 120 m. on the average.

URALIAN

Poshan Series. Dark-coloured shales and yellowish or grey sandstones with some 10 seams of workable coal and 3 to 4 beds of limestone intercalated in the lower part of the series. The limestones contain *Parafusulina vulgaris* (SCHELLW.), *P. vulgaris* var. *globosa* (SCHELLW.), *P. vulgaris* var. *watanabei* LEE, *P. valida* (LEE), *P. valida* var. *exigua* LEE, *Parafusulina richthofeni* (SCHWAGER), *Schwagerina princeps* EHRENB., *Quasifusulina longissima* (MÖLLER), *Marginifera pusilla* SCHELLW., *M. longispinus* var. *orientalis* CHAO, *Productus taiyuanfuensis* GR., *P. echidniformis* (GR.), *Spirifer fasciger* KEYS., *S. taiyuanensis* CHAO, *S.* (*Brachythyrina*) cf. *strangwaysi* VERNEUIL, *Lophocarinophyllum acanthiseptum* GR., *Chonetes*, *Martinia*, *Hustedia*, *Naticopsis* and *Loxonema*. Thickness 160 m.

M. CARBON.

Penchi Series. Yellowish and sometimes purplish shales with argillaceous limestone and bands of calcareous concretions near the top, and some clay-ironstones at the bottom. The limestone contains *Fusulina quasicylindrica* (LEE), *Choristites mosquensis* FISCHER, *Productus gratiosus* var. *occidentalis* SCHELLW, and *Phillipsia* cf. *kansuensis* LOCZY. Thickness about 45 m. Only definitely known in the Changchiu coalfield.

ORDOVICIAN

Tsinan Limestone. Massive, brownish-grey limestone, fine and dense in texture, somewhat dolomitic in composition, becoming thin-bedded and interstratified with argillaceous layers or thin shales towards the base. The upper part of this formation has yielded *Actinoceras richthofeni* FRECH, *A. coulingi* GR., *A. suanpanoides* GR., *A. submarginale* GR., *A. curvatum* GR., *Cyrtactinoceras frechi* GR., *Stereoplasmoceras pseudoseptatum* GR., *S. machiakounense* GR., *S. actinoceriforme* GR., *Gonioceras shantungense* GR. and *Asaphus boehmi* LORENZ. Thickness 850 m.

U. CAMBRIAN

Kaolishan Formation. Thin-bedded limestone of grey and ochreous colour, often oolitic, with a few intercalated layers of limestone-conglomerate and shale, and with a thick bed of limestone-conglomerate at the top. Fauna: *Clonograptus ? cambria* SUN, *Quadraticephalus walcotti* SUN, *Q. howelli* SUN, *Ptychaspis angulata* var. *sinensis* SUN, *P. ceto* WALC., *P. subglobosa* GR., *Saukia acamus* (WALC.), *S. tieni* SUN, *Sinosaukia pustulosa* SUN, *Conokephalina waltheri* SUN, *Pagodia richthofeni* KOBAYASHI, *Prosaukia tawenkowensis* SUN, *Illænurus (Tsinania) ceres* WALC., *Mansuyia tani* SUN, *Obolus taianensis* SUN, *Billingsella pumpellyi* WALC., *Orthis (Plectorthis) pagoda* WALC., *O. (P.) kayseri* WALC., *Platyceras clytia* WALC., *Orthotheca cyrene* WALC. Thickness about 23 m.

Tawenkou Formation. Bluish-grey, hard limestone usually well-bedded, occasionally slabby or conglomeratic, locally intercalated with shales. Fauna: *Agnostus cyclopygeformis* SUN, *Taishania taianensis* SUN, *Mansuyia orientalis* (GR.), *Tingecephalus granulosus* SUN, *Chuangia batia* WALC., *C. tawenkowensis* SUN, *C. subquadrangulata* SUN, *C. transversalis* KOBAYASHI, *C. yuani* SUN, *Illænurus (Tsinania) canens* WALC.?, *Pseudosolenopleura kotoi* (KOBAY.) SUN, *Wentsunia granulosa* SUN, *Changshanocephalus reedi* SUN, *Taianocephalus grabaui* SUN. Thickness 75-90 m.

[NOTE.—The Kaolishan and Tawenkou Formations are partially, if not wholly, equivalent to the Chaumitien Limestone which contains *Pagodia, Illænurus, Ptychaspis, Dikelocephalus, Bathyurus?, Plectorthis, Syntrophia, Hyolithes* and other genera commonly found in the Kaolishan and Tawenkou Formations. Total thickness of the Chaumitien Limestone is estimated at 180 m.]

M. CAMBRIAN

Kushan Shale. Green, nodular shale interbedded with thin layers of dense limestone. Fauna: *Acrothele minuta* WALCOTT, *Dicellomus parvus* WALCOTT, *Obolus (Westonia) blackwelderi* WALCOTT, *Agnostus chinensis* DAMES, *A. kushanensis* WALCOTT, *Stephanocare richthofeni* MONKE, *S. sinensis* (BERGERON), *Blackwelderia sinensis* (BERGE.), *Drepanura premesnili* (BERGE.), *D ketteleri* MONKE, *Ptychoparia tenes* WALCOTT, *Liostracina krausei* MONKE, *Redlichia finalis* WALCOTT, *Shantungia spinifera* WALCOTT. Thickness 15-36 m.

Changhia Oolite. Conglomeratic limestone of grey or ochreous colour at the top, followed by grey, dense limestones, often coarsely crystalline and occasionally oolitic, then by dark, massive, oolitic or globulitic limestones, becoming platy or shaly towards the base. Fossils: *Dorypyge richthofeni* DAMES (especially abundant), *Anomocare tutia* WALCOTT, *A. eriopia* WALCOTT, *A. temenus* WALCOTT, *A. ? dualis* WALCOTT, *A. latelimbatum* DAMES, *A. minus* DAMES, *A. decelus* WALCOTT, *A. biston* WALCOTT, *A. daunus* WALCOTT, *Anomocarella chinensis* WALCOTT, *A. contigua* WALCOTT, *A. albion* WALCOTT, *Dolichometopus deois* WALCOTT, *D. dirce* WALCOTT, *D. alceste* WALCOTT, *Agraulos dryas* WALCOTT, *A. abrata* WALCOTT, *A. abaris* WALCOTT, *A. dolon* WALCOTT, *A. dirce* WALCOTT, *A. divi* WALCOTT, *A.*

M. CAMBRIAN

ocalle WALCOTT, *A. agenor* WALCOTT, *Ptychoparia* (*Liostracus*) *intermedia* WALCOTT, *P.* (*L.*) *tutia* WALCOTT, *P.* (*L.*) *toxeus* WALCOTT, *P. trogus* WALCOTT, *P. titiana* WALCOTT, *P. tenes* WALCOTT, *P. theano* WALCOTT, *P. tellus* WALCOTT, *Damesella brevicaudata* WALCOTT, *D. blackwelderi* WALCOTT, *D. bellagranulata* WALCOTT, *Menocephalus belenus* WALCOTT, *M. admeta* WALCOTT, *M. adrastia* WALCOTT, *M. acerius* WALCOTT, *M. agave* WALCOTT, *Solenopleura abderus* WALCOTT, *S. acantha* WALCOTT, *S. agno* WALCOTT, *S. acidalia* WALCOTT, *Crepicephalus damia* WALCOTT, *C. magnus* WALCOTT, *Blackwelderia alastor* WALCOTT, *Teinistion alcon* WALCOTT, *T. typicalis* WALCOTT, *Acrotreta pacifica*, WALCOTT, *Obolus minimus* WALCOTT, *O. obscura* WALCOTT, *O.* (*Lingulella*) *damesi* WALCOTT, *O.* (*Westonia*) *blackwelderi* WALCOTT, *Platyceras chronus* WALCOTT, *Hyolithes cybele* WALCOTT, *Orthotheca delphus* WALCOTT. Thickness 150-200 m.

L. CAMBRIAN

Manto Shale. Red and brown shales with interbedded grey and buff limestones. Locally earthy limestones attain an appreciable thickness in the basal part. Fossils: *Ptychoparia mantoensis* WALCOTT, *P. ligea* WALCOTT, *P. impar* WALCOTT, *P. aclis* WALCOTT, *P. granulosa* WALCOTT, *P. constricta* WALCOTT, *Redlichia nobilis* WALCOTT, *Billingsella richthofeni* WALCOTT, *Hyolithes delia* WALCOTT. Thickness 135-225 m.

Archæan. Schists, gneisses, gneissose granite and metamorphosed basic rocks known as the Taishan Complex.

(10) NORTHERN KIANGSU

Loess. Yellowish grey loess, probably belonging to the Malan Stage.

Loam with numerous limy concretions, about 3 m. thick on the average.

Sandstones with layers of gypsum, local in distribution and insignificant in thickness.

PERMIAN

Tungshan Series. Yellow sandstones and black shales with two important seams of coal. Thickness about 40 m.

Takouyen Sandstone. White and light grey sandstones, often conglomeratic, with light and dark grey shale and shaly sandstones in the upper and lower parts and a few layers of inferior coal. Thickness about 70 m.

URALIAN

Chingshanchuan Series. Interbedded sandstones and shales containing, at intervals, several beds of limestone, with ferruginous red sandstone or irregular beds of iron-ores at the bottom. In certain facies these basal beds are replaced by fireclay and flints. Thin layers of coal occur at several horizons. None, however, is of economic value. Thickness about 60 m.

M. CARBON.

Chuanwangtou Limestone. White limestone, exceedingly pure in composition and fine in texture with *Fusulinella bocki* MÖLLER, *Fusulina cylindrica* FISCHER and *Choristites* cf. *mosquensis*, merging into thin-bedded black limestone interstratified with shales at the base. Basal conglomerate sometimes present. Thickness 150 m.

ORDOVICIAN

Actinoceras Limestone. Upper part, dense, blue limestone with a few flints and scattered individuals of *Actinoceras* in the top beds; lower part, thin-bedded, often flexuous or even locally contorted. Thickness 350 m.

Chiawang Shale. Ochreous shales and shaly limestones readily weathering to lumps of ochre, particularly well-developed in the neighbourhood of the Chiawang coalfield. Thickness 10-15 m.

Sanshantze Limestone. Grey or whitish grey, crystalline limestone, highly silicified in the upper part, becoming a pure blue limestone towards the base. A reddish limestone-conglomerate sometimes present at the base. Thickness 300-500 m.

CAMBRIAN

Thin-bedded Limestone. Ash-grey, thin-bedded limestone, partly shaly, locally crystalline and conglomeratic; wurmkalk frequently intercalated. Thickness 200 m.

Oolitic Limestone. Thick-bedded, oolitic limestone, generally dark brown in colour. Thickness 260 m.

Manto Shale. Red and yellow shales intercalated with numerous thin beds of limestone. Thickness 210 m.

SINIAN

Mianshan Limestone. Grey to black limestone, usually dense in texture, locally silicified, sometimes intercalated with purple shale. Thickness 480 m.

Chengshan Quartzite. White quartzite interbedded with sandstones and shales, and with conglomerate at the base. Thickness 120 m.

Wutai Formation. Mica- and chlorite-schists with occasional marble and schistose quartzite. Thickness 5,000 m.

Archæan. Gneisses and mica-schists.

(11) CENTRAL HONAN

Loess containing fresh-water shells and land snails.

Reddish Loam, 5-6 m. thick.

Red Loam, mottled, with numerous limy concretions. Thickness 10-15 m.

Gravel, about 3 m. thick.

PERMO-TRIAS

Sanfengshan Sandstone. Red sandstone with occasional layers of shale in the upper part, white, quartz-sandstone in the middle part and coarse, arkose sandstone in the lower part. Thickness 400 m.

PERMIAN

Tafengkou Series. Yellow, grey and purple shales and sandstones containing several important seams of coal. *Gigantopteris nicotianæfolia* SCHENK, *Annularites* and *Pecopteris* occur in the middle part. Thickness 280 m.

Shenhou Series. Yellowish-grey shales and sandstones with thin seams of coal and fireclay in the upper part, but sandstone becomes more predominating in the lower part, with a thick seam of coal near the base. Plant remains similar to those found in the Shansi Series abound in shales immediately above the main coal seam. Total thickness about 70 m.

URALIAN

Chutun Series. Pale red, grey and greenish-grey sandstones and shales or sandy shales, fireclay and layers of coal intercalated with 3 beds of marine limestone containing fusulinids, capped by a coarse white sandstone. Iron ores often occur near the base. Thickness 40-50 m.

ORD.

Chuetzeshan Limestone. Upper part, light to dark grey, thick-bedded limestone often traversed by calcite veins; lower part, thin-bedded grey limestone with shaly partings. Total thickness 300 m.

CAMB.

Litzukou Series. Wurmkalk, oolitic limestone with thin beds of dolomitic limestone merging downward into red and green shales intercalated with earthy limestone. Thickness 350 m.

Sinian Quartzite, red and grey in colour. Thickness 250 m.

Wutai Schist with marble.

(12) NORTHERN HONAN

Malan Loess. Yellow-grey loess with or without basal gravel containing *Struthiolithus* eggs and Helicidæ.

Reddish Loam. Reddish loam, fine and homogeneous in composition with occasional gravels in the basal part. Thickness up to 50 m.

PLIOCENE

Upper Sanmen Series. Upper part, sands passing laterally into clays; lower part, gravels passing laterally into coarse sands containing *Planorbis, Lamprotula,* Artiodactyles and questionable remains of *Elephas.* Thickness 10-20 m. These gravels sometimes rest immediately upon Eocene beds.

PLIOCENE

Lower Sanmen Series. Upper part, laminated clay of uniform greenish-grey colour with occasional lenses of coarse, yellowish sand towards the top yielding *Lamprotula;* middle part, cross-bedded sand intercalated with layers of gravel, not infrequently cemented by lime to form a somewhat indurated sandstone; lower part, buff to brown clay with sandy intercalations. Land and fresh-water shells of heavy type and fish teeth are particularly abundant in this clay. *Lamprotula antiqua* Odhner, *Solenaia carinata* Heude, *Anodonta woodiana* Lea, *Cuneopsis maximus* Odhner, *Nodularia douglasiæ* Griffith and Pidgeon, *Lepidodesma ponderosa* Odhner, *Hyriopsis descendens* Odhner, *Cristaria herculea* Middendorf, *Corbicula fluminea* Müller, *Limnæa clessini* Neumayr, *Metodonta houaiensis* Crosse, *Cathaica* (*Pseudiberus*) *plectotropis* v. Martens, *Platypetasus anderssoni* Odhner, *Melania*, *Planorbis*, *Cyprinus*, *Ctenopharyngodon*, *Hypophthalmichthys*, together with remains of Trionychids, *Elephas*, turtles and deer, are scattered in the formation. Thickness 50-60 m., of which the upper sand occupies the largest part.

EOCENE

Pinglu Series. Greenish-grey marl and yellowish-grey clay passing downward into a homogeneous clay of reddish colour interstratified with layers of conglomerate and gypsum. This is followed lower down by red and chocolate claystone and marls with important seams of gypsum. Still farther down lies a thick series of conglomerates which become coarser towards the base. Thickness 500 m.

Red Sandstone. Often intercalated with red shale; the latter becomes more dominant in the lower part. Thickness at least 500 m. Probably Triassic.

L. PERMIAN AND URALIAN

Shihhotze Shale. Mainly yellow shale with a few green shales and thin-bedded sandstones.

Taiyuan Series. Yellow, grey, blue and black shales and sandstones intercalated with 5 or 6 thin beds of limestone in the northern part of the area, but only one limestone, 20 to 30 m. thick, in the southern part. *Schwagerina princeps* Ehrenb., *S. tinvenkiangi* Lee, *Parafusulina crucaria* (Schwager), *P. pailensis* (Schwag.), *P. complicata* (Schellw.), *Pseudofusulina alpina* (Schellw.), *P. vulgaris* var. *watanabei* Lee, *P. anderssoni* (Staff and Wedekind), *Triticites regularis* (Schellw.) and *T. pusillus* (Schellw.) occur in the thick bed of limestone. Several seams of workable coal are intercalated in the upper part of the series. A thick, grey sandstone is usually present at the top, and a red shale with iron-ores at the base. Thickness about 300 m.

ORD.

Actinoceras Limestone. Thick-bedded, dark grey limestone with a basal conglomerate consisting of pebbles of limestone, *Actinoceras* being the leading fossil. Thickness 800 m.

Wurmkalk and **Oolitic Limestones** rich in trilobites, including *Ptychaspis shansiensis* Sun, *Prosaukia brizo* (Walc.), *Calvinella ulrichi*

SUN, *Tsinania canens* var. *shansiensis* SUN and *Pterocephalus bursilis* merging downward into a red shale intercalated with limestones. Cambrian.

Sinian Quartzite. Yellowish brown in colour, often false-bedded and ripple-marked. Basal conglomerate sometimes present. Thickness 50-100 m.

Archæan Gneiss invaded by basic igneous rocks.

(13) CENTRAL TAIHANG RANGE

Loess and Tufa. Yellowish-grey loess, partly primary and partly re-worked, often traversed by vertical tubes, easily breaking off vertically. Irregular-shaped concretions of lime and land snails are fairly common. Occasionally interstratified with layers of gravel. Thickness rarely exceeds 100 m. Tufas are only deposited in the limestone valleys in which numerous springs carry dissolved lime and deposit it along the streams forming occasionally dissected terraces. The well-known variety at Chinghsing is made up of an intricate system of delicate tubes and is widely used for ornamental purposes.

Sands and Clays with gravels in the lower part, well-developed in the Taiyuan Plain on the western side of the central Taihang. Thickness about 88 m. On the eastern side of the central Taihang the loess is sometimes immediately underlain by gravels and red clays. Near the village of Nanyeli, about 80 km. west of Chengting, the gravel is well cemented to form a conglomerate attaining a thickness of 1.5 m. This is underlain by reddish-brown and dark red clays, the latter containing pebbles and boulders. The red clay yields remains of *Rhinoceros* cf. *sinensis* OWEN, *Hyæna sinensis* Ow., *Equus, Sus, Cervus, Gazella, Ovis, Nemorhædus, Canis, Ursus, Machairodus* and *Hystrix,* indicating uppermost Pliocene or Lower Pleistocene age.

Basalt. Rich in decomposed olivine, occurring in small patches but at numerous localities. Thickness 20-30 m. Age: probably Oligocene.

Hipparion Clay. Red clay with bands of sand and beds of gravel or conglomerate in the lower part. Lime concretions are often abundant. Bones of *Hipparion, Hyæna, Rhinoceros* and fragments of turtle frequently occur in the concretionary masses. Thickness up to 90 m. Particularly well-developed in the Shouyang Basin.

Red sandstone. Thickness over 500 m. Probably Triassic.

Reddish brown shales interstratified with white sandstones sometimes conglomeratic. Thickness about 260 m.

PERMIAN

Shihchienfeng Series. Upper part: fine-grained sandstone, well-bedded, often in alternating black and white layers. Thin layers of brown shale and beds of chocolate marl are intercalated in the sandstone. Ripple-marks and cross-bedding are common. Conglomerates occasionally occur at the base. Lower part: Greenish and yellowish shales, claystones interbedded with dull red and greyish-white sandstones containing ill-preserved plants. Total thickness 400 m.

PERMIAN

Lower Shihhotze Series. Sandstones, shales and clays or marls predominantly yellow in colour, but sometimes brown, grey or even purple argillaceous layers are present. A thick, quartzose sandstone, or millstone, forms the top part, and an arkose sandstone the bottom part of this series; clay ironstones of no great thickness occur in the middle. *Pecopteris, Annularia* and other well-preserved plants are found in the yellow and grey shales. Thickness about 110-130 m.

URALIAN

Taiyuan Series. Dark-coloured shales and yellowish sandstones with numerous coal-seams and 5 or 6 beds of limestone intercalated in the series. Nodules of clay-ironstone often abound in lenticular beds of pottery-clay which is extensively excavated for the ceramic industry. The limestone beds, each of which is given a local name, are all richly fossiliferous. The leading forms among the foraminifera are: *Parafusulina expansa* (LEE), *P. richthofeni* (SCHWAGER), *P. japonica* (GÜMBEL)?, *P. complicata* (SCHELLW.), *Pseudofusulina nathorsti* (STAFF and WEDEKIND), *P. lutugini* SCHELLW., *P. erucaria* (SCHWAGER), *P. subnathorsti* (LEE), *Quasifusulina longissima* (MÖLLER), *Triticites regularis* (SCHELLW.), *T. parvulus* (SCHELLW.), *T. simplex* var., *Schwagerina* sp. Anthozoa: *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* GR., *Pinnatophyllum wongi* GR. Brachiopoda: *Spirifer taiyuanensis* CHAO, *S. fasciger* KEYSERLING, *S. pankouensis* GR., *S.* (*Brachythyris*) *strangwaysi* var., *Productus taiyuanfuensis* GR., *P. uralicus* TSCHERNYSCHEW, *P. semireticulatus* MARTIN, *P.* (*Echinoconchus*) *punctatus* MARTIN, *Marginifera pusilla* SCHELLW., *Rhipidomella michelinoides* GR. and CHAO, *Spiriferina willsii* GR., *Choristites pavlovi* STUCKENBERG, *C. trautscholdi* STUCKENB., *C. norini* CHAO, *Squamularia echinata* CHAO. Pelecypoda: *Parallelodon chiliensis* CHAO, *P. tieni* CHAO, *Astartella adenticulata* JAKOWLEW, *Cypricardinia sinensis* CHAO, *C. subelegans* CHAO, *Palæolucina carbonaria* CHAO, *Acanthopecten carboniferus* STEVENS, *Deltopecten giganteus* CHAO, *D. multistriatus* CHAO. Gastropoda: *Ptychomphalus tieni* YIN, *Solenospira cochleoides* YIN, *Euomphalus* (*Phymatifer*) *fragilis* YIN, *Naticopsis deformis* YIN. Cephalopoda: *Apheleceras falciferum* YIN, *A.* cf. *mosquense* (TZWETAEV), *Pleuronautilus ornatissimus* YIN, *Huangoceras linchengense* YIN, *Temnocheilus* sp. Crinoidea: *Sinocrinus microgranulosus* TIEN, *S. houkouensis* TIEN, *S. linchengensis* TIEN, *Eupachycrinus pustulosa* TIEN. Thickness 100-190 m.

M. CARBON.

Penchi Series. Mainly shales without coal, with one or two thin layers of crinoidal limestone yielding *Bradyina nautiliformis* MÖLLER, *Fusulina konnoi* (OZAWA), and *F. pankouensis* (LEE). Thickness 10-20 m. Only definitely known in the Pingting Basin, Shansi.

ORDOVICIAN

Actinoceras Limestone. Bluish and grey limestones, massive and thick-bedded, with occasional shaly partings. The top of this limestone is always deeply weathered and iron-stained. The irregular cracks and fissures in the top beds are always impregnated with leached iron oxide. Sometimes pockets or other irregular-shaped bodies of iron ore occur between this limestone and the overlying Penchi or Taiyuan Series. *Actinoceras richthofeni* FRECH, *A. tani* GR., *Eccyliopterus kushanensis* GR., *E. tangshanensis* GR. and *Strophomena incurvata* (SHEPARD) are found in the upper part of this limestone, and *Maclurea* cf. *magna* lower in the sequence. Thickness 820 m., forming the main range of the central Taihang.

Cameroceras Limestone. Sandy limestone and siliceous limestone with flints followed downward by more sandy limestone. A thick bed of limestone-conglomerate appears in the lower part. In this bed are intercalated yellow and green shales (the Chiawang Shale?) and fine porcelain clay. *Cameroceras* occurs in the lower sandy limestone. Basal conglomerate sometimes observed. Thickness 274 m.

CAMBRIAN

Wolungshan Formation. Wurmkalk, thick-bedded limestone of grey or bluish colour and limestone-conglomerate in the upper part, passing downward into limy shales of green, yellow and brown colours intercalated with lenticular beds of limestone. Fossils in the upper part: *Sinosaukia pustulosa* SUN, *Calvinella? ulrichi* SUN, *Pagodia damesi* KOBAYASHI, *Tsinania ceres* WALCOTT, *T. tingtaohengi* SUN, *Ptychaspis brevicus* SUN, *Wedekindia cylindrica* SUN. These belong to the Fengshan Stage according to SUN. Fossils in the lower part: *Kaolishania pustulosa* SUN, *K. transita* SUN, *K. westargardi* SUN, *Agnostus cyclopygeformis* SUN, *Tingocephalus granulosus* SUN, *Conocephalina belus* WALCOTT, *Bathyuriscus wongi* SUN, *Chuangia curvata* SUN, *C. batia* WALCOTT, *C. convexa* SUN, *Changshanocephalus reedi* SUN, *Blackwelderia sinensis* var. *linchengensis* SUN, *B. tieni* SUN, *Stephanocare richthofeni* MONKE, *Wongia triangulata* SUN, *Teinistion subconica* SUN, *Drepanura* sp., and *Obolus linchengensis* SUN. Thickness about 30 m.

Changhia Limestone. Thick-bedded bluish limestone and compact oolites with thin-bedded crystalline limestone at the base. Thickness 100-130 m.

Manto Formation. Upper part, mainly red shales with some greenish mudstones and a few red sandstones, usually full of mica flakes and occasionally ripple-marked; middle part, dense but thin-bedded grey limestone; lower part, red or reddish brown shales with lenticular beds of reddish limestone and hæmatite. Total thickness about 100 m.

SINIAN

Huailu Limestone. Siliceous limestone, generally thin-bedded and pinkish or greyish in colour, intercalated with brown and black shales. Black flints occur in abundance. Some of them show peculiarly laminated structures sometimes referred to *Collenia* or *Newlandia*. Thickness about 120 m. near Huailu, but thins out towards the south-west.

SINIAN

Tsangyen Quartzite. Fine-grained quartzite, often false-bedded, mostly white in the upper part, containing reddish-brown sandy shales and slates with beds of poor hæmatite in the middle part, and pinkish quartzite in the lower part. Ripple-marks and sun-cracks are frequently met with towards the base. Maximum thickness about 200 m. at the Tsangyenshan, but decreases towards the north-east.

Wutai Formation. Gneisses, quartzites, chlorite- and mica-schists and marble, often invaded by porphyries and cut by quartz veins. Exposed in the Chinghsing, Yuanshih and Tsanhuang districts.

(14) NORTHERN SHANSI

Loess. Yellowish-grey loess with occasional basal gravel. A dozen volcanic cones occur over an area of 60 km., about 30 km. east of Tatung. These volcanoes of the Stromboli type came into existence in Loess time.

Reddish Loam. Only locally developed, variable in thickness, containing *Helix*, *Siphneus arvicolinus* and *S. tingi*.

Nihowan Beds. Lacustrine marls, clays, sands and gravels yielding *Lamprotula*, *Cuneopsis*, *Corbicula*, *Pisidium*, *Limnæa*, *Planorbis*, *Vulpes chikushanensis* YOUNG, *Canis* (*Nyctereutes*) *sinensis*, *C. chihliensis* ZD., *Ursus* cf. *etruscus*, *Hyæna* cf. *sinensis*, *Lutra licenti* TEILH. and PIV., *Mustela pachygnatha* TEILH. and PIV., *Meles* sp., *Felis* sp., *Cynailurus pleistocænicus* ZD., *Machairodus nihowanensis* TEILH. and PIV., *Ochotonoides complicidens* (BOULE and TEILH.), *Alætaga* sp., *Siphneus tingi* YOUNG, *S. arvicolinus* NEHRING, *Hystrix* sp., *Rhinoceros* cf. *mercki*, *R.* cf. *tichorhinus*, *Elasmotherium* sp., *Cirotherium* sp., *Hipparion* (*Proboscidipparion*) *sinensis* SEFVE, *Equus sanmenensis* TEILH. and PIV., *Sus* sp., *Camelus* (*Paracamelus*) *gigas* SCHL., *Cervulus* sp., *Cervus* (*Eucladoceras*) *boulei* TEILH. and PIV., *C.* (*Rusa*) *elegans* TEILH. and PIV., *Gazella sinensis* TEILH. and PIV., *Spiroceras wongi* TEILH. and PIV., *Ovis shantungensis* MATSUMOTO, *Bison palæosinensis* TEILH. and PIV. and *Elephas* cf. *planifrons* or cf. *nomadicus*. The deposits tend to become coarser towards the lower part of the series and towards the margin of the Nihowan Basin in the Sangkanho Valley. Thickness about 200 m.

Hipparion Clay. Red clay intercalated with inconstant beds of gravel and lenses of sand. Basal gravel often present with pebbles embedded in a grey matrix. In the Paotuh district, north-western Shansi, this clay attains a thickness of 65 m., including 4 m. of basal gravel. In the middle part of the clay occurs a concretionary layer full of animal remains. They belong to *Hipparion richthofeni* KOKEN, *Telecoceras*, *Aceratherium*, *Sinotherium lagrelii* RINGSTRÖM, *Anchitherium*, *Hyæna*, Viverridæ, Felidæ, *Canis sinensis*, *Machairodus*, *Hyænarchus*, Mustelidæ, *Mastodon*, *Stegodon*, *Elephas*, *Chilinotherium tingii* WIMAN, *Prosiphneus*, *Sus*, antelopes, deer, rodents, birds and reptiles.

Lutzekou Beds. These lacustrine deposits are only developed in the Paotuh district, north-western Shansi. The uppermost part of the deposits consists of reddish loess-like material with fragments of bones and rhinocerotid teeth. This is followed down by stratified white marl with a greenish tinge containing mammalian remains and molluscs. Then follows a cross-bedded yellow sand with rhinocerotids, again marls of greenish-yellow colour and argillaceous limestone with fishes and molluscs, and finally a gravel with fragments of bones and mammalian teeth resting directly upon the Palæozoic Formation. The whole sequence reaches a thickness of 25-30 m. Some consider these beds as a basal part of the Hipparion Formation, others would regard them as a separate stratigraphical unit of pre-Pliocene age.

Kouchiapu Conglomerate. Massive conglomerate with numerous pebbles of basalt, associated with sands, clays and fresh-water limestone of dark red colour. So far only known in the Tatung Basin. Oligocene or Miocene?.

Basalts intercalated with, and underlain by, fossiliferous clays, sands and conglomerates. These deposits are only 10-12 m. thick. In places they contain a seam of lignite. Probably of Oligocene or Miocene age.

Hunyuan Formation. Massive clay-rock of dark purplish colour with subconchoidal fracture, containing numerous well-preserved specimens of *Corbicula anderssoni* Gr. Only exposed in the Hunyuan district. Cretaceous.

JURASSIC

Chiulung Series? Sandstones and shales of red, brown and green colours. Thickness varies considerably.

Tatung or **Ningwu Coal-bearing Series.** Chiefly grey or white sandstones and green or black shales with 4 seams of bituminous coal. *Baiera, Pterophyllum, Dicksonia, Podozamites* and *Asplenium* occur in the shales. Thickness 260-480 m.

Cross-bedded red sandstone, locally developed in northern Shansi. Probably Triassic.

Shansi Series. Sandstones dominating in the upper and lower parts, and shales in the middle part. Thickness 100-200 m. Permian.

URALIAN

Taiyuan Series. Shales, important coal-seams and limestones containing *Euphemus wongi* Gr., *Bucaniopsis calamitoides* (Gr.), *Shansiella altispiralis* (Gr.), *Mourlonia nana* Yin, *Naticopsis deformis* Yin, *Lissochilina tumenensis* Yin, *Sphærodoma subglobosa* Gr., *Soleniscus brevis* White, *S. mucronatus* Yin, *Schizodus shansiensis* Chao, *Edmondia nystromi* Chao, *Myalina swallovi* McChesney, *Allorisma regularis* King, *Pseudomonotis shansiensis* Chao, *Cœlonautilus planotergatus* (McCoy), *Remeleoceras subquadrangulare* Gr., *R. grabaui* Yin, *Temnocheilus asiatica* Gr., *Huanghoceras simplico-*

URALIAN

statum GR., *H. wangi* YIN, *Pleuronautilus* cf. *dorso-armatus* (ABICH), *Orthoceras* sp., *Productus taiyuanfuensis* GR., *P.* (*Linoproductus*) *cora* D'ORB., *Buxtonia juresanensis* (TSCHERNYS.), *Aulacorhynchus paotechowensis* GR. and CHAO, *Chonetes carboniferus* KEYSERLING, and *Martinia semiglobosa* TSCHERNYS. The marine beds are well-developed in the Paotuh district, north-western Shansi, where the highest marine zone is called the Tumen Shale, the middle, the Paotuh Limestone and the lower the Paloukou Limestone. The faunas are, however, essentially of the same age. Thickness about 50 m.

M. CARBON.

Penchi Series. Shales with thin seams of coal and some sandstones. A bed of limestone occurs near the top of the series yielding *Staffella sphæroidea* (MÖLLER), *Spirifer* (*Choristites*) *fasciger* KEYS., *Choristites myatschkovensis* var. *sinensis* CHAO, *C. mosquensis* FISCHER, *C. trautscholdi* STUCKENBERG, *C. wangchuchueni* CHAO, and *Martinia changchiakouensis* CHAO. Thickness 50-60 m.

ORD.

Upper Kichou Limestone. Dark-coloured massive limestone, sometimes dolomitic, yielding *Actinoceras* in the upper part, which is undoubtedly to be correlated with the Machiakou Limestone. The lower part of this formation probably belongs to the Lower Ordovician. Total thickness 600 m. or more.

CAMBRIAN

Lower Kichou Limestone. Upper part, ochreous grey limestones partly conglomeratic (wurmkalk) and dense, and partly massive and thick-bedded with a hard, blue limestone capping the series; lower part, comparatively thin-bedded limestones interstratified with grey or brown calcareous shales which are now and then charged with limestone nodules. The limestone beds are often full of oolites, which are particularly well-developed at an horizon some 35 m. from the base. These oolitic beds are rather massive, dark grey in colour, and attain a thickness of 14 m. The upper part of the limestone contains *Plectorthis kayseri* WALC., *Ptychaspis bella* WALC., *Blackwelderia cilix* WALC., *Agraulos regularis* WALC., and the lower part contains *Dorypyge richthofeni* DAMES, *D. richthofeni lævis* WALC., *Ptychoparia vesta* WALC., *P. nereio* WALC., *P. inflata* WALC., *P. undata* WALC., *P. comus* WALC., *P. lilia* WALC., *Agraulos obscura* WALC., *A. vicina* WALC., *A. nitida* WALC., *A. uta* WALC., *A. armatus* WALC., *Dolichometopus hyrie* WALC., *Anomocare bigsbyi* WALC., *A. flava* WALC., *Anomocarella irma* WALC., *Solenopleura pauperata* WALC., *Acrotreta shantungensis* WALC., *Obolus shansiensis* WALC.?, *O. obscurus* WALC., *Orthotheca glabra* WALC., *Platyceras willisi* WALC., *Scenella dilatatus* WALC., *Plectorthis kichouensis* WALC., and *Yorkia? orientalis* WALC. Total thickness about 180 m.

Manto Shale. Red shales with thin beds of argillaceous limestone, sometimes reddish and sometimes yellowish in colour, and with red sandstone and conglomerate at the base. Thickness 55-110 m.

SINIAN

Huto Limestone. Grey siliceous limestone with abundant chert becoming intercalated with purple slates towards the lower part. Thickness 900 m. or more.

Toutsun Slate. Grey to purple slates with beds of limestone, quartzite and conglomerate. Thickness 1,000-1,800 m.

Wutai Formation. See p. 57.

Archæan. See p. 46.

(15) Central Shansi

Loess. Yellowish-grey loess rarely with basal gravel.

Reddish Loam. Often with concretionary bands which are marked by a slight change of colour, vertically elongated, and more or less regularly spaced, yielding *Ochotona complicidens* Boule and Teilh., *Siphneus* cf. *fontanieri* Miln.-Edw. Thickness up to 26 m. towards the mountains.

Taiku Beds. Yellowish or reddish-brown sands with thin layers locally hardened to a sandstone, capped in places by a dark marl. Numerous mammalian remains are found in the upper part of the formation belonging to *Meles*, *Canis* (*Nyctereutes*) *sinensis* Schl., *Felis* cf. *lynx* L., *F.* cf. *pardus* L., *Siphneus tingi* Young, *Ochotonoides complicidens* (Boule and Teilh.), *Rhinoceros* cf. *mercki*, *R.* cf. *tichorhinus*, *Hipparion* (*Proboscidipparion?*), *Equus sanmeniensis* Teilh. and Piv., *Camelus* (*Paracamelus*), *Rusa*, *Cervus* cf. *boulei* Teilh. and Piv., *Gazella sinensis* Teilh. and Piv., *Bison* cf. *palæosinensis* Teilh. and Piv., Ovibovid? These are essentially equivalent to the Nihowan fauna of uppermost Pliocene age. In the lower part of the formation a somewhat older fauna appears, including *Lutra*, *Dipoides majori* Schl., *Chilotherium*, *Rhinoceros* cf. *orientalis* Schl., *Hipparion* cf. *richthofeni* Koken, *Moschus*, *Gazella* cf. *blacki* Teilh. and Young, *Antilospira*, *Mastodon borsoni* Hays, and *Stegodon yushensis* Young. These fossils are largely found in lacustrine marls. In a greenish or bluish marl fresh-water shells, such as *Limnæa*, *Planorbis* and thin-shelled unionids, are embedded together with fishes, including a gold-fish [*Carassius auratus* (Linnæus)] and plant remains which are referred to *Picea*, *Cyperacites*, *Ulmus shansiensis* Chaney, *Ribes barbouri* Chaney, *Amelanchier wongi* Chaney, *Acer pliocenicum* Chaney, *A. taikuensis* Chaney, *Leguminosites chinensis* Chaney. A bed of gravel is usually present at the base. Thickness about 100 m. or more.

Hipparion Formation. Dark red sandstone or clay and conglomerate with large boulders at the base. The leading faunal elements in the red sandstone or clay are: *Canis* (*Nyctereutes*) *sinensis*

SCHL., *Parataxidea, Hyænarctos, Ictitherium, Hyæna* cf. *variabilis* ZD., *Machairodus palanderi* ZD., *Acerotherium, Chilotherium, Rhinoceros* (*Dicerorhinus*) *orientalis* SCHL., *Hipparion richthofeni* KOKEN, *Sus erymanthius* R. and W., *Chleuastochœrus stehlini* PEARSON, *Gazella* cf. *paotehensis* TEILH. and YOUNG, *Procapreolus, Cervavus, Trilophodon wimani* HOPWOOD, *Tetralophodon, Mastodon borsoni* HAYS, *Stegodon yushensis* YOUNG and *S. zdanskyi* HOPWOOD. On top of the clay facies, a concretionary layer is often present to mark it off from the overlying reddish clay or loam. Thickness of the *Hipparion* clay about 12 m. on the average. The basal conglomerate is usually well-cemented, and fairly persistent along the headwaters of the Fenho, having a thickness of 2 m.

Jurassic sandstone only developed in the northern part of the area, *e.g.*, in the Chinglo district.

Shihchienfeng Series. Upper part, medium-grained sandstone, largely red or brown in colour, often mottled and cross-bedded, now and then intercalated with layers of blue-grey shales and chocolate-coloured clay; about 500 m. thick. Lower part, chocolate-coloured shales with crusts of travertine at intervals, intercalated with beds of gypsiferous sandstone; about 130 m. thick. Equivalent to the Husung and Matou Series of C. C. Wang. Probably Triassic.

PERMIAN

Upper Shihhotze Series. Chocolate-coloured shales predominating in the upper part, capped by chalcedony beds and intercalated, at intervals, with grey, greenish or yellowish layers of sandy shales, claystones and some sandstones; dark-coloured shales prevail in the lower part with a few yellow, lateritic sandstones. *Gigantopteris* flora flourishes in this formation. The more important elements are: *Annularites ensifolius* HALLE, *A. lingulatus* H., *A. heianensis* (KODAIRA), *Annularia mucronata* SCHENK, *A. crassiuscula* H., *Asterophyllites longifolius* (STERNB.) BRONGN., *Sphenophyllum verticillatum* (SCHLOTH.) BRONGN., *S. thonii* var. *minor* STERZEL, *S. sino-coreanum* YABE, *Bowmanites* sp., *Sphenopteris nystromii* H., *S. taiyuanensis* H., *S. tingii* H., *S. norinii* H., *Pecopteris* (*Asterotheca*) *orientalis* (SCHENK) POTONIÉ, *P.* (*A.*) *norinii* H., *P. anderssonii* H., *P. arcuata* H., *P. lativenosa* H., *P.* (*A.*) *hemiteloides* BRONGN., *P. anthriscifolia* (GOEPP.) ZAL., *Odontopteris* (*Dicroidium?*) *orbicularis* H., *O.* (*Callipteris?*) *laceratifolia* H., *Neuropteris* sp., *Neuropteridium polymorphum* H., *N. nervosum* H., *Protoblechnum wongii* H., *Tæniopteris nystrœmii* H., *T. taiyuanensis* H., *T. densissima* H., *Gigantopteris nicotianæfolia* SCHENK, *G. lagrelii* H., *Chiropteris reniformis* KAWASAKI, *Lepidodendron oculus-felis* ABBADO and ZEIL., *Lepidostrobus* sp., *Cordaites principalis* (GERM.) GEIN., *Baiera tenuistriata* H., *B. spinosa* H., *Saportæa nervosa* H., *Samaropsis sinensis* H., *Psygmophyllum multipartitum* H., *Plagiozamites oblongifolius* H., and *Tingia crassinervis* H. Thickness 280 m.

PERMIAN

Lower Shihhotze Series. (Shansi Series?). Grey, greenish and yellowish shales and light-coloured marls intercalated with sandstones which become more prominent in the basal part. Thin layers of black shale and coal occasionally occur. Flora: *Annularites sinensis* H., *Annularia gracilescens* H., *A. mucronata* SCHENK, *Macrostachya huttoniæformis* H., *Sphenophyllum emarginatum* BRONGN., *S. oblongifolium* (GERM. and KAULF.) UNG., *S. thonii* MAHR, *S. thonii* var. *minor* STERZEL, *S. costæ* STERZEL, *S. rotundatum* H., *S. fimbriatum* H., *Bowmanites laxus* H., *Sphenopteris pseudogermanica* H., *S. tenuis* SCHENK, *Oligocarpia* (*Sphenopteris*) *gothanii* H., *Chansitheca* (*Sphenopteris*) *palæosilvana* REGÉ, *Pecopteris arcuata* H., *P. taiyuanensis* H., *Cladophlebis nystrœmii* H., *Alethopteris norinii* H., *Callipteridium trigonum* FRANKE, *Odontopteris subcrenulata* (ROST) ZEIL., *Emplectopteris triangularis* H., *Protoblechnum wongi* H., *Tæniopteris multinervis* WEISS, *T. latecostata* H., *T. nystrœmii* H., *T.* cf. *schenki* STERZEL, *T. shansiensis* H., *T. serrulata* H., *Gigantopteris lagrelii* H., *G. whitei* H., *Stigmaria ficoides* (STERNB.) BRONGN., *Cordaites principalis* (GERM.) GEIN., *C. schenkii* H., *Plagiozamites oblongifolius* H., *Tingia carbonica* (SCHENK) H. Thickness 160 m.

URALIAN

Taiyuan Series. Shales often rich in iron pyrites, coal-seams, subordinate sandstones and 4 or 5 beds of limestone intercalated in the series, each a few metres thick. Flora: *Annularia* cf. *pseudostellata* POTONIÉ, *Sphenophyllum oblongifolium* (GERM. and KAULF.) UNG., *Sphenopteris* sp., *Pecopteris* cf. *feminæformis* (SCHLOTH.) STERZEL, *Alethopteris* sp., *Callipteridium trigonum* FRANKE, *Neuropteris* sp., *Lepidodendron gaudryi* RENAULT, *Stigmaria ficoides* (STERNB.) BRONGN., *Cordaites schenkii* H. Fauna: *Quasifusulina longissima* (MÖLLER), *Parafusulina expansa* (LEE), *P. complicata* (SCHELLW.), *P. richthofeni* (SCHWAGER), *Pseudofusulina nathorsti* (STAFF and WEDEKIND), *P. nathorsti* var. *laxa* (LEE), *P. subnathorsti* (LEE), *P. vulgaris* var. *fusiformis* (SCHELLW.) LEE, *P. valida* var. *exigua* (LEE), *Triticites simplex* var. *minuta* (LEE), *Boultonia willsi* LEE, *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* GR., *L.* (*Sinophyllum*) *pendulum* GR., *Lopholasma carbonaria* GR., *Pinnatophyllum norini* GR., *Cyclonema carbonaria* YIN, *Naticopsis hemistriata* GR., *Sphærodoma depressa* YIN, *Euphemus* sp., *Pleuronautilus nodosostriatus* YIN, *P. pernodosus* GR., *Remeleoceras transitorius* YIN, *Huanghoceras* sp., *Allorisma regularis* KING, *Conocardium norini* CHAO, *Entolium aviculatum* SWALLOW, *Lima striatoplicata* CHAO, *Aviculopecten alternatoplicatus* CHAO, *Acanthopecten carboniferus* STEVENS, *Productus semireticulatus* MARTIN, *P. taiyuanfuensis* GR., *P.* (*Echinoconchus*) *punctatus* MARTIN, *P.* (*Linoproductus*) *koninckianus* VERNEUIL, *Marginifera pusilla* SCHELLW., *M. lopingensis* var. *orientalis* CHAO, *Avonia echidniformis* (GR.), *Chonetes pygmæus* LOCZY, *C. latesinuatus* SCHELLW., *C. carboniferus* KEYS., *Choristites pavlovi* STUCKENBERG, *C. norini* CHAO, *Brachythyrina strangwaysi* VERNEUIL, *Squamularia echinata* CHAO, *Brachythyris shansiensis* CHAO, *Martinia semiglobosa*

URALIAN

TSCHERNYS., *Spirifer taiyuanensis* CHAO. These beds are locally known as the **Yuemenkou Series.** It has a thickness of about 100 m., though the exact boundary between this and the underlying series has not yet been definitely established.

M. CARBON.

Penchi Series. Sandy shales, coal-seams and a few sandstones with one bed of limestone, the Pankou Limestone, in the lower part. This limestone contains *Staffella sphæroidea* (MÖLLER), *Fusulina schellwieni* (STAFF), *F. pankouensis* (LEE), *F. quasicylindrica* (LEE), *Spirifer* (*Brachythyrina*) *strangwaysi* VERNEUIL, and *Enteletes lamarcki* FISCHER. Thickness about 60 m.

ORD.

Actinoceras Limestone. Massive, thick-bedded grey limestone, uniform in lithological character throughout the sequence. Thickness about 800 m.

CAMBRIAN

Thin-bedded Limestone partly conglomeratic, occasionally intercalated with layers of shales, about 160 m. thick.

Oolitic Limestone. Massive, grey or greenish limestone full of oolites. Thickness about 260 m.

Manto Shale. Red shales and sandstones with occasional basal conglomerate. Thickness about 80 m.

Sinian Quartzite. Thickness 0-60 m.

Wutai Formation. Chiefly chlorite- and mica-schists.

Archæan. Gneisses with pegmatite dykes.

(16) SHENSI BASIN

Loess. Yellowish-grey loess with scattered calcareous concretions of small size and irregular shape, tending to break off vertically. Basal gravel usually present, consisting of rolled bodies of calcareous concretions. Nowhere does it attain a thickness of more than 50 m.

Reddish Loam. Loam or loamy clay of brown or reddish-brown colour with numerous calcareous concretions of lenticular or irregular shape arranged in horizontal bands. Towards the eastern margin of the basin, the reddish loam apparently merges into a more sandy or loessic facies, somewhat ashy-grey in colour, and is sometimes named the **Yulin Formation** after the name of the district where it is typically developed. *Siphneus* cf. *fontanieri* MILNE-EDWARDS, *Ochotonoides complicidens* BOULE and TEILH., *Equus*, deer and *Helix* have been found in this deposit. Gravels usually present at the base. Thickness 200-250 m.

Red Clay. Essentially red clay with some red sand interstratified in the clay and a well-cemented conglomerate at the base. Thickness 30-50 m. Probably equivalent to the Hipparion Formation.

CRETACEOUS

Tienchi Beds. Gypsiferous deposits.

Hwanhsien Series. Bright greenish shales and sandstones. Thickness 200 m.

Kingyang Series. Alternating green and red sandstones and shales. Thickness 600-800 m.

Tanpai Sandstone. Mainly red sandstones and some shales intercalated with a few greenish strata. Maximum thickness 200 m., absent in places.

Hwachi Sandstone. Regularly bedded red sandstone with a few intercalated shales. Thickness 330 m.

Loho Sandstone. False-bedded sandstone of dark red colour, almost entirely free from argillaceous layers, prone to weathering into crumbly sand. Thickness 600-700 m.

JURASSIC

Anting Limestone. Thin-bedded argillaceous limestone, reddish in colour and more or less conglomeratic at the top, becoming shaly and full of limy nodules, towards the base. Thickness 20-70 m. Only developed in the northern part of the basin. It is believed to be replaced by the **Ichuan Conglomerate,** 170 m. thick, in the southern part. Ganoid fish belonging to Pholadopholidæ characteristic of the Upper Jurassic of Europe have been procured from the uppermost layer of this limestone.

Shensi or Wayaopo Series. Grey sandstones and shales in the upper part without coal-seams, but with a few plant remains among which *Dioonites brongniarti* SEWARD is present. The lower part is also composed of grey or white sandstones and green or grey to black shales carrying coal-seams. The grey sandstone is petroliferous in several horizons. From the lower part of this series Liassic or Rhætic plants have been obtained. They include *Cladophlebis* (*Todites*) *williamsoni* BRONGN., cf. *Baiera tæniata* BRAUN, *Sagenopteris nilssoniana* BRONGN., *Pityophyllum nordenskioldi* (HEER). In the northern part of the basin contemporaneous lava flows occur in a position slightly above the coal-seams.

TRIASSIC — Puhsien Formation?

Yenchang Series. Upper part: grey quartzose sandstone with subordinate green or black shale. Cross-bedding and local non-sequences are common. *Schizoneura paradoxa* SCHIMPER, *S. gondwanensis* FEISTM., *Equisetites* sp., *Asterocarpus virginiensis* var. *obtusilobus* FONTAINE, *Dichopteris* sp., *Amentum* sp., *Æthophyllum* sp., *Cladophlebis chinensis* PAN, *C. szeiana* PAN, *C. gigantea* OISHI, *Danæopsis hughesi* FEISTM., *D.* (*Pseudodanæopsis*) *hallei* PAN, and *Thinnfeldia nordenskioldi* NATH. have been found in a grey shale inter-

TRIASSIC

Puhsien Formation?

calated in the grey sandstone. Lower part: largely arkose sandstone with a thin layer of black shale near the bottom carrying bivalves and numerous fish-scales. The Yenchang and Yunping oil-bearing beds are closely associated with this shale. From other horizons *Cladophlebis shensiensis* PAN, *Danæopsis hughesi* FEISTM., *Ginkgo magnifolia* (FONTAINE), *Bernoullia* sp., *Voltzia* cf. *heterophylla* BRONGN. and *Amentum* sp. have been collected. Total thickness about 1,000 m.

Shihchienfeng Series. Dark red sandstones alternating with reddish green shales in the upper part, and red shales alternating with thin, red sandstones in the lower part. Basal conglomerate is developed from place to place with well-rounded pebbles of sandstone and limestone in a red matrix. Thickness about 600 m.

PERMIAN

Shihhotze Series. Upper part: largely sandstones, often hard and siliceous, with subordinate shales, usually greyish-white, buff, dull red, or reddish-grey in colour. Dark grey or even black layers are sometimes present. With these are occasionally associated thin coal-seams of inferior quality. Lower part: largely shales intercalated with micaceous sandstones prone to weathering, predominantly purplish in colour, sometimes greenish-grey or yellowish-green, and occasionally buff. The harder variety of the sandstones is extensively used for the manufacture of millstones, and the shales, which are often rich in iron pyrites, are mined for extracting sulphur. Coal-seams only occur in the lower horizons. Both the upper and lower parts of this series have yielded plant remains, including *Cordaites principalis* (GERM.) GEIN., *Lepidodendron* cf. *obovatum* STERN., *Calamites*, *Sphenophyllum* and *Tæniopteris*. Total thickness probably over 700 m. Exposed along the south-western extension of the Luliang Range on the south-eastern border of the basin.

Taiyuan Series?. Dark shales and sandstones with coal-seams and fireclay. So far, only a single bed of shaly limestone has been observed in the coal-mines. Only exposed along the south-eastern margin of the basin.

Ordovician limestone. Thick or thin-bedded limestone, usually dark grey in colour, sometimes bluish-white and sometimes pinkish. The thin-bedded part appears to represent the upper division and the massive, thick-bedded facies the lower. Immediately below the thin-bedded limestone lies a limestone-breccia which persists over a considerable area. A layer of fine shale, bluish- or yellowish-grey in colour, highly alkaline in composition, is intercalated in the lower part of the thin-bedded limestone. This, again, is a persistent stratum. It has been mined for many centuries, and extensively used as a glaze in the porcelain industry. Ordovician fossils referred to *Lophospira*, *Rafinesquina*, *Dalmanella* cf. *testudinaria* (DALM.), *Plectorthis*, and *Orthis* have been collected from this limestone. Its thickness is estimated at no less than 2,500 m. (?). A part of this may belong to the Cambrian. Exposed on the south-eastern border of the basin.

(17) Alashan and Ordos

Loess. Yellowish-grey loess, probably belonging to the Malan Stage, merging laterally into lacustrine sands and muds. In the Sjara-osso-gol district, sournern Ordos, the lacustrine deposits contain an Upper Pleistocene fauna, comprising *Canis*, *Nyctereutes*, *Hyæna*, *Siphneus fontanieri* MILN.-EDW. (and other modern types), *Rhinoceros tichorhinus*, *Equus* cf. *przewalkskyi*, *E. hemionus*, *Camelus knoblochi*, *Cervus*, *Elaphus*, *Gazella*, *Bubalus*, *Bos* and *Elephas nomadicus*.

Boulder Beds and **Gravels.**

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Santaoho Formation. Sands and conglomerates with layers of clay carrying bones of *Mastodon*, *Rhinoceros*, *Chalicotherium*, *Hyæna*, *Felis* and *Trogulus*, probably of Pliocene age.

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Mesozoic conglomerates and **sandstones.** Thickness 200-300 m.

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Talapai Formation. White and reddish sandstones, often coal-bearing with layers of fossiliferous limestone and black shale associated with the coal-seams. Fossils: *Gastrioceras wongi* GR., *Productus hemisphæricus* KUTORGA, *Trepospira? kansuensis* GR., *Pterinopecten papyraceus* (SOW.), *Posidoniella yuani* GR., *P.* cf. *pyriformis* HIND, *Aviculopecten kansuensis* GR., *Lingula credneri* GEINITZ. Thickness 1,000 m. Permian.

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Sohanpu Formation. Red shales with some sandstones rich in gypsum. Base not exposed.

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Tongkow Shale. Fine, black slates of massive appearance, containing *Didymograptus euodus* LAPW., *Climacograptus teilhardi* GR., *C. licenti* GR., *Dicellograptus* sp. Middle Ordovician.

Dense, well-bedded, dark limestone, probably Lower Ordovician.

Sinian Formation. Massive, siliceous limestone in the upper part, quartzites in lower part often bearing rain-prints. The limestone is thrust over the metamorphosed Permian formation from the west in the main range of the Alashan, the quartzite being often squeezed out.

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Pre-Sinian marble.

(18) Eastern Kansu

Loess. Yellowish-grey loess with calcareous concretions. Thickness from a veneer to 500 m.?

Sanmen Beds. Lacustrine marl with unionids and conglomerates in the lower part, some 36 m. thick. In certain facies these beds are replaced by yellowish-green and black sands with calcareous gravel at the base, varying in thickness from 15 to 18 m.

Hipparion Clay. Red clay with a bone bed in which remains of *Hipparion richthofeni* KOKEN are present.

Kueiteh or **Kuyuan Series.** Red and white sandstones, usually well-bedded and coarse-grained, containing gypsum and fresh-water limestone in places. Conglomerates are sometimes present at the base. Thickness up to 1,000 m. Probably Eocene.

Cretaceous Formation. Represented by two facies of unequal thickness. West of the Lungshan Range the Cretaceous formation is named the **Yaochieh Series,** composed mainly of red sandstone in the upper part, grey papery shale in the lower part, and coal-bearing shale with clayey limestone nodules at the base. Remains of a fossil shark belonging to *Hybodus* are sometimes included in the limestone nodules. Total thickness about 200 m. The eastern facies begins to appear in the neighbourhood of the Lungshan, and attains a mighty development in and to the east of that range. This **Liupanshan Formation,** as it is called, mainly consists of green, red and white sandstones and green and bluish-green shales with two oolitic limestones near the bottom and several thin layers of limestones near the top. *Lycoptera kansuensis* GR. and *L. woodwardi* GR. occur in the laminated limestone, and *Estheria kansuensis* CHI in the shales. Thickness about 2,500 m.

Jurassic Formation. White, green and red sandstones and shales with coal-seams containing *Cladophlebis, Ginkgo, Baiera, Equisetites* and *Podozamites lanceolatus* (L. and H.). Only 200 m. thick in the western part of the area, but increasing to 2,000 m. in the eastern part.

Hsienhuashan Series. Reddish and yellowish quartzose sandstones, containing *Lepidodendron oculus* in the basal part. Thickness no less than 2,000 m. Probably ranging from Permian to Triassic.

Talapai and **Chouniukou Series.** Upper part, black shales and sandstones with several important seams of coal and plant remains, such as *Sigillaria* and *Cordaites;* lower part, sandstones and shales with several beds of limestone.

Nanshan Series. Green schists, phyllites, slates, quartzites, with white, siliceous limestones prevailing in the upper part and yielding *Pachypora* and *Favosites.* The limestones attain a thickness of about 150 m., and the thickness of the whole metamorphic series is estimated at no less than 2,000 m.

[NOTE.—In the Pingliang district, the easternmost part of Kansu, Ordovician limestone is overlain by the Pingliang Shale, scarcely metamorphosed. This shale contains *Climacograptus bicornis* HALL, *C. parvus* HALL, *Didymograptus sagitticaulis* GURLEY, *D. serratulus* HALL, *Dicellograptus divaricatus* (HALL), *Nemagraptus exilis* LAPW., *N. gracilis* (HALL), *Dicranograptus* cf. *furcatus* (HALL), *D. clingani* CARRUTHERS, *Diplograptus angustifolius* HALL, *D. teretiusculus* var. and *Orthograptus whitfieldi* (HALL).]

Archæan. Gneisses, schists and gneissoid granite.

(19) North-Western Kansu

Loess and **lacustrine sands.**

Red sandstone of great thickness, probably Triassic.

Shansi Series. Variegated sandstones with a few shales and inferior coal-seams. Fossil plants occasionally occur. Thickness 340 m. Permian.

Uralian

Taiyuan Series. Shales intercalated with 6 or 7 beds of limestone, each rarely exceeding 2 m. in thickness. Sandstones are comparatively rare. Coal-seams occasionally attain workable value. Fossils in the limestones: *Quasifusulina longissima* (Möller), *Schwagerina fusulinoides* Schellw., *Triticites simplex* (Schellw.), *T. incisa* (Schellw.), *T. parvulus* (Schellw.), *Pseudofusulina prisca* (Möller), *Parafusulina complicata* (Schellw.), *P. richthofeni* (Schwager), *P. oblonga* (Ozawa), *Productus punctatus* Martin, *P. taiyuanfuensis* Gr., *P. cora* d'Orb., *P. uresanensis* Tschernys., *Marginifera loczyi* Chao, *M. pusilla* Schellw., *Reticularia rundata* Gr., *Chonetes granulifer* var. *asiatica* Chao, *C. jungchangensis* Chao, *C. carboniferus* Keys., *Spirifer bisulcatus* Sow. var., *S. pankouensis* Gr., *Rhipidomella michelinoides* Gr. and Chao, *Orthotetes crenistria* Phill., *Phillipsia kansuensis* Loczy, *Hustedia bella* Gr., *Euomphalus*, *Bellerophon*, *Loxonema*. Thickness 50-114 m.

M. Carboniferous

Penchi Series. Shales and sandstones with one or two beds of limestone; thickness undetermined. The limestones contain *Bradyina nautiliformis* Möller, *Fusulina quasicylindrica* Lee, *F. præsimplex* Lee, *Productus gruenewaldti* Krotow, *P. gratiosus* var. *occidentalis* Schellw., *P.* (*Linoproductus*) *cora* d'Orb., *Avonia echidniformis* Gr. and Chao, *Marginifera loczyi* Chao, *Mancella sowerbyi* Fischer, *Choristites loczyi* Fredericks, *C. gobicus* Chao, *C. yuani* Chao, *C. yanghukouensis* Chao, *Brachythyrina strangwaysi* Verneuil, *Squamularia echinata* Chao, *S. ovata* Chao, *Martinia semiconvexa* Chao, *M. undatifera* Chao, *Chonetes carboniferus* Keys., *C. granulifer* Owen var. *asiatica* Chao, *C. pygmæa* Loczy, *Bellerophon acutocarinatus* Yin, *B. yuani* Yin, *Bucania subtilistriata* Yin, *Stachella inflata* Yin, *Solenospira quinquecostata* Yin, *S. amæna* (de Kon.), *S.* cf. *fischeri* (Stuckenb.), *S.* aff. *conjungens* (Waagen), *S. cochleoides* Yin, *Naticopsis kansuensis* Yin, *Trachydomia verrucosa* Yin, *Zygopleura* cf. *ignorata* (Trautschold), *Z.* cf. *crassa* Wanner, *Meekospira acuminata* (Goldfuss), *Soleniscus ventricosus* (Hall), *Solenocheilus maokouensis* Yin, *Nucula yuani* Chao, *Nuculopsis anthraconeiloides* Chao, *Schizodus* cf. *rossicus* Verneuil, *Astartella adenticulata* Jakowlew, *Conocardium kansuensis* Chao, *Allorisma regularis* King, and *Streblopteria* cf. *sericea* Verneuil.

L. CARBONIFEROUS

Chouniukou Formation. Upper part, blue and grey limestones interbedded with shales, about 68 m. thick; lower part, sandstones, shales and quartzites with plant remains, about 67 m. thick. The marine beds in the upper part contain *Productus inflatus* TSCHERNYS., *P.* (*Linoproductus*) *tenuistriatus* VERNEUIL, *P.* (*Echinoconchus*) *elegans* McCOY, *P.* (*E.*) *perplexus* CHAO, *P.* (*E.*) *liangchowensis* CHAO, *Marginifera viseeniana* CHAO, *Buxtonia scabricula* (MARTIN), *Striatifera kansuensis* CHAO, *Striatifera undata* (DEFR.), *Striatifera maxima* (McCOY), *Avonia grabaui* CHAO, *Chonetes hardrensis* var. *kansuensis* CHAO, *C. semicircularis* CHAO, *C. papilionacea* PHILL., *Kansuella kansuensis* CHAO, *Krotovia grabaui* CHAO, *Spirifer liangchowensis* CHAO, *Brachythyrina kansuensis* CHAO, *Squamularia chouniukouensis* CHAO, *S. pustula* CHAO, *Rhipidomella michelini* L'EV., *Orthotetes crenistria* PHILL., *Spiriferina laminosa* McCOY, *Leptæna analoga* PHILL., *Athyris ingens* DE KON., *Schizophoria resupinata* MARTIN, *Lithostrotion portlocki* (BRONN) and *Phillipsia* sp.

Nanshan Series. Metamorphosed sandstones, shales, phyllites and limestones.

(20) WESTERN TSINLING

Huihsien Series. Soft sandstone, red shale and limestone-conglomerate, 200 m. thick, probably Eocene.

CRETACEOUS?

Tungho Conglomerate. Coarse conglomerate with well-rounded pebbles of limestone, slates and quartzites, and containing beds of sandstone and layers of greenish clay in the upper part, but the pebbles are usually sub-angular in the lower part; well-developed in the Funghsien district. Thickness about 300 m.

JURASSIC

Mienhsien Series. Greenish-grey and purple slaty shale containing a seam of inferior coal and a thick stratum of conglomerate. In the basal part conglomerate is also present. Fossil plants occur at several horizons, and include *Cladophlebis* (*Todites*) *williamsoni* (BRONGN.) SEW., *Podozamites lanceolatus* (LIND. and HUTT.), *Pityophyllum nordenskioldi* NATH., *Elatocladus* sp., and *Equisetites* sp. Thickness 1,000 m.

Chenan Series. Thin-bedded grey limestone and grey or black shale containing poor coal-seams and a few beds of sandstone. Thickness 2,000-3,000 m. Age: Carboniferous or Permian.

L. CARBON.

Lioyang Limestone. Dark grey to black limestone, usually massive, with *Lophophyllum* (*Koninckophyllum*) *acrophylloides* YU, sometimes thin-bedded with shaly and sandy intercalations. *Cyathophyllum lioyangensis* YU, *Siphonodendron* aff. *irregulare* PHILL., and *S.* aff. *martini* E. and H. occur in the shaly limestone. Thickness 1,000-1,500 m.

Ketaszu Slate. Well-laminated slaty shale of dark green or greenish-grey colour. Thickness 2,000-3,000 m. Age: Devonian to Carboniferous.

DEVONIAN

Kutaoling Limestone. Thick-bedded dark grey limestone, with shales and quartzitic sandstones in the basal part and a conglomerate at the base yielding Devonian corals. Thickness about 500 m. This limestone is believed to be equivalent to the **Chiangyou Series** developed on the southern border of the western Tsinling, *i.e.*, equivalent to the Tangwangchai Limestone, the Peishihpu Limestone and the Pingyoupu Sandstone put together.

[NOTE.—The fossils collected from Maoerchuan and Wangchia, about 25 km. south-east of Chenghsien, southern Kansu, are probably derived from this formation. The Maoerchuan fauna consists of *Leptostrophia mccarthyi* GR., *Chonetes orientalis* LOCZY, *Productella subaculeata* var. *kansuensis* GR., *P. productoides* var. *sinensis* GR., *Rhipidomella kutsingensis* GR., *Schizophoria striatula* mut., *S. macfarlanii* var. *kansuensis* GR., *Camarotoechia* cf. *gigantea* MANS., *Hypothyridina cuboides* var. *sinensis* GR., *Douvillina interstrialis* (PHILL.), *Atrypa bodini* MANS., *A. desquamata* var. *kansuensis* GR., *Gypidula planisinosa* GR., *Stringocephalus transversa* GR., *Emanuella takwanensis* (KAYS.). The Wangchia fauna comprises *Leptostrophia mccarthyi* GR., *Camarophoria sutschuanensis* LOCZY, *C. leticnsiformis* GR., *C. wangchiaensis* GR., *C. changuliensis* GR., *C. huotiformis* GR., *Pugnax pugnus* var. *sinensis* GR., *Atrypa douvillii* MANS., *A. reticularis* LINNÆUS, *A. aspera* var. *chunguliensis* GR., *A. sinensis* KAYS., *Emanuella transversa* GR., *Idospirifer changuliensis* GR., *Reticularia lensiformis* GR., *Cyrtina heteroclita* var. *sinensis* GR., *Athyrisina quadriplicata* GR.]

Shihwengtzu Limestone. Thick-bedded, dark grey limestone, frequently intercalated with bands of chert, somewhat shaly and yielding Silurian corals in certain facies. Thickness about 700 m.

Tsoshui Series. Thick-bedded quartzites with bands of slate, green and purple phyllite and occasional marble. Thickness and age undetermined.

Tsinling System. Schists and gneiss probably partly Wutai and partly Archæan.

(21) EASTERN PART OF THE MIDDLE TSINLING

PLEIST.?

Grey sand and **loam.**

Mottled Red Loam with numerous calcareous concretions.

Subangular Boulders and Blocks irregularly set in a yellowish sandy matrix like moraine.

Thick Conglomerate with well rounded pebbles.

TERT.

Nanyang Formation. Dark red concretionary clays, white sands and marls, gravels and thick conglomerates having a total thickness of up to 3,000 m.

Andesitic flows characterized by the presence of large phenocrysts of felspar; probably Cretaceous.

Slates and **limestones** of considerable thickness, probably Silurian and Devonian in age.

Sinian Formation. Siliceous limestones on the southern side of the main range, and quartzites on the northern side of it.

Granitized gneisses, schists and amphibolite with occasional layers of graphite developed on the southern side of the main range; extensively exposed in the axial part of the range; probably belonging partly to the Wutai.

(22) NORTHERN SZECHUAN AND TAPASHAN

Reddish Yellow Loam with much sand and numerous pockets of gravel in the basal part. Calcareous concretions are common; typically developed near Hanchung.

Loose and **coarse gravels** mixed with yellowish tenacious clay forming terraces along the Min and other rivers and also extensive sheets in the plain now dissected into isolated patches. Those surrounding the Chengtu Plain are particularly impressive. In the middle part of the Red Basin this gravel attains a thickness of about 30 m., but towards the margin it increases to 60 m.

CRETACEOUS

Changtsiangyen Sandstone. Brick-red, soft, coarse sandstone, often cross-bedded, with intercalations of clay-shale and a basal conglomerate; typically developed at Changtsiangyen, near Kuangyuan. Thickness over 1,000 m.

[NOTE.—This series seems to be equivalent to the Kiating Series of Heim, Tan and Lee. Chao and Huang, who proposed this term, consider that this uppermost part of their Szechuan Series may possibly belong to the Tertiary. If these two terms be ultimately proved identical, it would be more convenient to keep only one term according to the claim of priority.]

Kuangyuan Series. Red sandstones and red clay-shales with intercalated layers of yellow sandstone, gypsum and lenses or nodules of calcareous substance.

Tsienfuyen Series. Red clay-shale and sandstone followed by yellow sandstone and yellowish green shale, and then by a coarse, basal conglomerate containing *Corbicula, Cyrena, Unio* and ***Estheria.*** This, together with the Kuangyuan Series, amounts to a thickness of 1,500 m.

Hsiangchi Series. Yellow sandstone intercalated with grey and black shales and workable coal-seams yielding Rhætic or Liassic plants. Thickness 400-500 m.

TRIAS

Kialing Limestone. Yellow to light-grey, thin-bedded, dolomitic limestone alternating with purple and yellowish shales in the lower part. Thickness 650 m.

Feisienkuan Series. Purple or purplish-red shale intercalated with thin layers of shaly limestone containing *Pseudomonotis griesbachi* BITTNER, *P.* sp., *Gervillia* cf. *cuneata* SANDBERGER, *Myophoria, Schizodus, Lingula* and *Pecten.* Thickness about 500 m.?

PERMIAN

Tayeh Limestone. Thin-bedded light grey limestone, with thin shales and coal in the lower part and containing *Gastrioceras zitteli* GEMM. 500 m. thick.

Wushan Limestone. Dark grey to black limestone, often massive, carrying bands and nodules of chert in the upper part with an occasional coal-seam near the top. *Tachylasma magnum* GR., *T. elongatum* GR., *Michelinia siyangensis* REED, *Caninia liangshanensis* HUANG, *Polythecalis* cf. *chinensis* (GIRTY) occur in the middle and upper parts of the limestone and *Tetrapora hanchungensis* HUANG at the base. *T. elegantula* has been obtained from the Chaotien district. Thickness about 350 m.

Liangshan Shale. Black shale with seams of inferior anthracite and fragments of plant remains. Thickness up to 50 m.

DEVONIAN

Tangwangchai Limestone. Massive, cliff-forming limestone passing into thin-bedded limestone at the base. *Yunnanella hanburii* (DAV.) collected near Hanchung probably belongs to this stage. Thickness over 1,000 m.

Peishihpu Limestone. Thick-bedded, grey limestone with a quartzitic sandstone in the upper part. The limestone contains numerous corals and brachiopods. Among them are: *Gypidula mansuyi* GR., *Atrypa desquamata* SOW., *A. richthofeni* (KAY.), *A. sinensis* (KAYSER), *A. bodini* MANSUY, *Leiorhynchus deprati* MANSUY, *Camarophoria schizoplicata* GR., *Hypothyridina parallelepipeda* BRONN, *H. lungtungpeiensis* (KAYSER), *Stringocephalus obesus* var. *grandis* GR. Several species of *Cyrtiopsis* such as *C. davidsoni* GR., *C. shansiensis* GR., *C. graciosa* GR., *C. transversa,* together with *Hypothyridina procuboides* (KAYSER), *Atrypa richthofeni* (KAYSER), *Schizophoria striatula, S. macfarlanii* (MEEK), *Productella subaculeata* MURCH., *Crania obsoleta* GOLDFUSS, and several species of *Sinospirifer sinensis* collected from the neighbourhood of Lungtung in the southern part of the western Tsinling probably belong to this stage. A variety of *Calceola* collected from Chaohua indicates the presence of a lower stage. Thickness about 1,000 m.

Pingyoupu Sandstone. Thick-bedded, reddish and grey quartzitic sandstone, about 3,000 m. thick.

SILURIAN

Sintan Formation. Greenish shale with occasional layers of nodular shaly limestone containing *Monograptus, Mesograptus* and numerous corals and brachiopods. These are: *Atrypa reticularis* LINN., *Meristina tumida* DALM., *Strophomena shonnsuenensis* KAYSER, *Spirifer elevatus* DALM., *S. interlineatus* SOW., *Orthis bouchardii* DALM., *Nucleospira pisiformis* HALL, *Rhynchonella borealis* var. *sinensis* KAYSER, *Ceriaster calamites* LINDSTROM, *Synamplexus viduus* (LIND.), *Amplexus appendiculatus* LIND., *Ptychophyllum cyathiformis* LIND., *Plasmopora tubulata* LONSDALE, *Halysites catenularia* LINN., *Heliolites interstinctus* LINN., *Alveolites, Platyphyllum, Cystiphyllum* and *Cyathophyllum*. The shaly facies of the formation is rather thin, and includes many beds of limestone in the Chaotien district on the southern side of the western Tsinling, but shale becomes more predominant and attains a thickness of 400 to 500 m. in the Tapashan region.

ORDOVICIAN

Chaupishan Series. Limestones, shales, black chert (lydianite) and siliceous conglomerate with *Trinucleus richthofeni* KAYSER, *Orthis calligramma* DALM. and *Plectambonites sericeus* SOW.

Pagoda Limestone. Thin-bedded, impure limestone, purplish-red or buff to yellow in colour crowded with *Orthoceras sinensis* FOORD. Thickness 100 m.

Neichiashan Shale. Greenish calcareous shale, somewhat sandy in the lower part. The leading fossils are: *Yangtzeella poloi* (MARTELLI), *Orthis calligramma* DALM., *Clitambonites giraldi* (MARTELLI), *Eccyliopterus sinensis* FRECH, *Calymene, Ampyx* and *Megalaspis*. Thickness 200 m.

Ichang Limestone. Massive, greyish-white limestone, often siliceous; well-developed in the Liangshan, near Hanchung, and in the Tapashan region. Thickness over 1,000 m.

(23) NORTH-WESTERN HUPEH

TERTIARY

Wushaoling Marl. Greyish-white marl containing sands and small rounded pebbles with a conglomerate at the base. Thickness up to 80 m.

Lianghokou Beds. Dark grey and black shales, often laminated, sometimes sandy and sometimes calcareous, intercalated with beds of conglomerate. Thickness about 70 m.

Fanchuang Series. Pale red and light grey marls intercalated with red sandstone, occasional conglomerates and seams of gypsum. *Lophialetes* and numerous fragments of animal bones occur in the grey marl and reddish clay-shales. Thickness 300-400 m.

Houho Slate. Bluish-grey slates with carbonaceous shales. Thickness 530 m. Rhætic or Jurassic.

Permian

Chushan Series. Dark grey and black limestones, shaly limestone and calcareous shale often altered to slate, phyllite and even schist; inferior coal-seams are associated with the carbonaceous shale, and crinoid stems occur in the limestone. Thickness several hundred metres.

Silurian

Shangtsin Series. Upper part, silver-grey slates and phyllites with beds of marmorized limestone near the top; middle part, greenish-grey calcareous slate, occasionally carbonaceous; lower part, buff sandy slates and phyllites with thin beds of limestone at the bottom.

Pingsikou Series. Upper part, greenish-grey and black slaty shales, often siliceous, capped with a bed of fossiliferous limestone. *Favosites* aff. *gothlandicus* Lam., *F. goldfussi* E. and H., *Syringopora* and *Orthis* occur in abundance. Lower part, black siliceous limestone passing downward into papery black shale. Total thickness about 900 m., probably partially equivalent to the Shangtsin Series.

Ordovician

Linlo Limestone. Yellowish-green shales and light green argillaceous limestones in the upper part, a little more than 80 m. in thickness, and an alternating series of dark grey and buff limestones in the lower part, over 1,000 m. thick. The upper part contains *Endoceras grabaui* Yu, *Vaginoceras wahlenbergi* Foord, *V. chientzkouense* Yu, *Orthoceras chinensis* Foord, *O.* cf. *politum* McCoy, *O. remotum* Yu, *O. densum* Yu, *Didymograptus murchisoni* Beck, *Orthis calligramma* Dalm., *Dalmanella* sp., *Leperditia* sp., *Asaphus gigas* var. *hupehensis* Sun, *Taihungshania shui* Sun, *Illænus nanchangensis* Sun, *Bathyurus minor* Sun and *Bronteus* sp.

Camb.

Nanhua Slate. Yellowish and bluish-grey slates and phyllites locally traversed by quartz veins, about 150 m. thick.

Sinian

Paisangkuan Limestone. Dark grey, well-bedded limestone, often siliceous, sometimes altered to pure, white marble intercalated with shales, slates and schists having a considerable thickness.

Heishui Series. Upper part, greenish and yellowish-grey slates; lower part, light and dark greenish-grey schists intercalated with altered coaly shale, beds of pure white marble and quartzite. Total thickness over 2,650 m.

Wutai

Wutang Schist. Dark chlorite schist, schistose quartzite, with occasional marble and paragneiss, often invaded by sills and dykes, and cut by numerous quartz veins.

(24) Tapeishan, North-Eastern Hupeh

Pleist.?

Red Clay with occasional basal gravel.

Huengtien Gravel. Loose gravel with well-rounded quartzite pebbles. Thickness up to 20 m.

TERT.

Pukow Sandstone? Red sandstone with conglomerates in the middle and lower parts, developed in low-lying areas and along the Yangtze.

CRET.

Panchiapu Series. Andesite and andesitic tuff, developed in the Huangmei and Chihchun districts on the southern side of the Tapeishan, and in the Shangcheng district on the northern side of the same range.

JURASSIC

Goma Sandstone. Sandstones often quartzose and barren of fossils in the Huangmei district on the southern side of the Tapeishan, but bearing plant remains and coal in the Shangcheng district on the northern side of the range.

TRIAS

Huangmaching Series. Purple sandstones and shales only developed in the Huangmei district. Thickness about 20 m.

Tayeh Limestone. Upper part, thick-bedded, dark grey limestone and conglomerate; about 150 m. thick. Middle part, thickly bedded, light grey limestone, each individual bed being made up of inseparable but well-marked laminæ; about 225 m. thick. Lower part, thin-bedded, bluish-grey to light grey limestone intercalated near the base with a yellowish-grey shale in which occur pelecypods and ammonites; about 380 m. thick.

PERMIAN

Loping Formation. Coal-bearing series with a black, bituminous limestone in the upper part, coal-bearing shale in the middle, and a few coarse-grained sandstones at the base. Thickness 20-50 m.

Wusueh Limestone. Greyish-white, close-grained limestone with cylindrical-shaped flints. Rich in *Doliolina lepida* SCHWAGER, *Verbeekina verbeeki* (GEINITZ), *Neoschwagerina craticulifera* (SCHWAGER), *Sumatrina annæ* VOLZ and other advanced types of fusulinids. Corals and trilobites also occur. Thickness varying from a few metres to 80 m.

Kuhfeng Formation. Well-bedded chert interstratified with grey shale and brown sandstone, the latter being usually richly fossiliferous. Thickness a few metres to 130 m.

Chihsia Limestone. Black, impure limestone often containing rows of bedded flints arranged along the bedding plane. Everywhere the limestone is characterized by the presence of a typical Chihsia fauna. In the lower part the limestone becomes highly bituminous and fœtid, and yields *Doliolina claudiæ* DEPRAT. Thickness about 120 m.

URAL.

Chuanshan Limestone. Usually absent; when present, it never attains a thickness of one metre.

M. CARB.

Huanglung Limestone. White and pink limestones with *Fusulinella bocki* MÖLLER, *Fusulina cylindrica* FISCHER, *Staffella sphæroidea* (MÖLLER) and corals. Thickness about 85 m.

L. CARBONIFEROUS

Kinling Limestone. Dark grey to black limestones with a greenish grey shale in the middle containing a Viséan fauna. Usually absent, but present in the Hanyang district. Total thickness about 30 m.

Wutung Sandstone. Quartzose sandstone white in the upper part, yellow in the lower part, with a seam of white fireclay in the middle. Only developed at Hanyang and east of Huangmei. Total thickness about 65 m.

SILURIAN

Sintan Shale. Upper part, yellow and green shales and sandstones with *Encrinurus rex* GR., having a maximum thickness of about 200 m.; middle part, an alternation of thin beds of grey limestone and yellow and green shales containing *Halysites* cf. *cratus* ETH., *H. hupehensis* GR., *Heliolites interstinctus* var. *yangtzeensis* GR., *H. bohemicus* WENTZEL, *Pselophyllum zaphrentiforme* GR. and *Pentamerus borealis* EICHWALD; thickness varying from 10 to 50 m. Lower part, yellow and green shales with *Climacograptus* cf. *scalaris* HIS., *Diplograptus cometa* GEIN., and *Monograptus regularis* TÖRNQ., having a thickness of 400 m.

SINIAN

Tongyin Limestone. Limestones with a few flints in the upper part passing downward into an alternation of thin-bedded limestone, chert and siliceous, black limestone with bedded flints; slaty shale intercalated with limestones and a hard, thin-bedded flinty limestone form the lower part. Thickness about 650 m.

Kunluling Series. An alternating series of bluish-grey, micaceous sandstone and micaceous phyllite. Thickness increases towards the west; over 1,000 m. in the Anlu and Suihsien districts.

WUTAI?

Tapei Group. Granitoid gneisses, mica-schists, amphibolites with occasional marble and graphite, quartzites and chlorite-schist forming the main range of the Tapeishan, often associated with igneous bodies, especially those of granite.

(25) CENTRAL AND WESTERN HUPEH

TERTIARY

Red Clay up to 200 m. thick.

Tunghu Sandstone. Coarse and yellowish-white sandstone in the upper part; sandstones with light-green marls and fresh-water limestones, locally full of *?Bithynia*, forming the middle part; soft red sandstone with a thick conglomerate at the base. Total thickness over 1,000 m.

CRETACEOUS

Kuichou Series. Hardened purple shale and thin-bedded green sandstone, about 1,000 m. thick, forming the upper part; another 1,000 m. of thick-bedded green sandstones intercalated with purple shales follow; this is succeeded by more green sandstones and shales, about 1,300 m. thick, with scattered specimens of small *Cyrena* and *Estheria middendorfi* JONES var. *sinensis* CHI; the basal part is mainly com-

CRETACEOUS

posed of yellowish-green shales and shaly sandstone crowded with *Unio cremeri* Frech, *U. chaoi* Gr., *U. johan-böhmi* Frech, *Cyrena kuichouensis* Gr., *C. hupehensis* Gr., *C. yangtzeensis* Chao, *C. hsiehi* Chao, *C. tahsiaense* Chao and *Mycetopus mengyinensis* Gr.; fossiliferous up to the horizon 1,500 m. from the base. Total thickness 3,500 m.; largely developed in the Kuichou Basin.

LIAS TO RHÆTIC

Hsiangchi Series. Divisible into three parts: upper part, mainly green sandstone with green, yellow, brown and black shales and several seams of coal. The sandstones and shales contain *Cyrena hsiangchiensis* Chao, *Podozamites lanceolatus* Lind. and Hutt., *Pterophyllum æquale* (Brong.), *Tæniopteris tenuinervis* Brauns, *Dictyophyllum nilssoni* (Brongn.), *Cladophlebis* cf. *denticulata, C. haiburnensis* (E. and H.) (Brongn.), *Czekanowskia rigida* Heer, *Sphenopteris, Thyrsopteris, Asplenium, Ctenis* and *Phœnicopsis;* middle part, conglomeratic sandstones with coal-bearing shales; lower part, yellow, brown and greenish shales with grey, yellow and white, soft sandstones containing occasional layers of fresh-water limestone and inferior seams of coal; plant remains abundant. Total thickness 450 m.

TRIAS

Patung Series. Chiefly purple shales which are divided into two parts by interbedded limestones and yellow shales in the middle of the series; the limestones yield *Spiriferina* and crinoids; upper purple shale about 150 m. thick, lower purple shale about 400 m. thick, with a yellow fissile shale at the base. Total thickness about 600 m.

Chinglung Limestone. Thin-bedded limestone usually light grey, but sometimes reddish in colour, occasionally with a conglomerate in the base. *Xenodiscus* aff. *lilangense* Krafft and *Ophiceras* sp. occur in the grey limestone, and *Sibirites* cf. *kingianus* Waagen, *Kashmirites obliquecostatus* Tien, *K.* aff. *subarmatus* Diener, *K.* aff. *acutangulatus* Welter, *Meekoceras* sp. occur in the reddish limestone. Thickness up to 1,500 m.

PERMIAN

Gastrioceras Shale. Yellowish-grey shale sometimes containing a layer of inferior coal and sometimes having a bed of hæmatite at the base. The shale yields *Gastrioceras* cf. *zitteli* Gemm., *Sphenotus* and *Modiomorpha.* Thickness 0-30 m.

Wushan Limestone. Dark grey, well-bedded limestone with numerous layers of flint or chert arranged along the bedding planes; sometimes intercalated with quartzite in the upper part; fossils are found in several horizons. In the uppermost part occur *Oldhamina* cf. *decipiens* (de Koninck), *Lyttonia richthofeni* Kayser, *Productus gratiosus* Waagen, *P. abichi* Waagen, *P. yangtzeensis* Chao, *P. sumatrensis* Rœmer var. *palliata* Kayser, *P. hemisphæricum* Kut., *Marginifera lopingensis* (Kayser), *Athyris damesi* Fliegel, *Reticularia lineatus* Martin, R. *waageni* Loczy, *Martinia worthi* Waagen var. *sulcata* Chao, *Liebia indica* Waagen, *Chonetes* sp., *Aviculopecten derajatensis* Waagen, *A. maccoyi* (Meek and Hayden), *A.* cf. *pseudoctenostreon*

PERMIAN

WAAGEN, *A. crebristriatus* DE KONINCK, *Pseudomonotis* sp., *Michelinia microstoma* YABE and HAYASAKA, *Polythecalis chinensis* (GIRTY), *Tetrapora* sp., *Zaphrentis* sp., *Siphonodendron* sp., *Monilopora* sp., *Vesotabularia tungliangensis* YU, *Fenestella* sp., *Fistulipora* sp. The middle part of the limestone is often crowded with *Neoschwagerina, Sumatrina, Verebeekina* and corals. The basal part is crowded with *Nankinella, Eoverbeekina, Sphærulina* and *Pisolina*. A bed of quartzite is often present at the base. Total thickness 260-500 m.

Coal-bearing Shale, about 30 m. thick, with a basal layer of crinoidal limestone, usually absent in western Hupeh, but sometimes present in the central part of the province; age undetermined.

SILURIAN

Sintan Shale. Divisible into three parts :—

Upper or **Shamao Series.** Grey to greenish-grey shales and sandstones becoming more sandy towards the top. Fossils : *Encrinurus (Coronocephalus) rex* GR., *Proëtus latilimbatus* GR., *Pentamerus borealis* EICHW., *Stropheodonta shonnsuenensis* (KAYSER), *Dalmanella* sp., *Nucleospira pisiformis* HALL, *Retzia* sp., *Conchidium tenuiplicatus* GR., *Enterolasma* sp. Thickness 320 m.

Middle or **Lojoping Series.** Mainly alternating beds of yellowish, sandy and calcareous shales with beds of impure limestone at the top and near the base. In certain facies, a hard, olive-green shale predominates. Fossils : *Favosites gothlandicus* LAM., *F. tachlowitzensis* BARR., *F. nucleolatus* GR., *Halysites* cf. *cratus* ETH., *Halysites hupehensis* GR., *Heliolites bohemicus* WENTZEL, *H. decipiens* MCCOY, *H. interstinctus* var. *yangtzeensis* GR., *Palæocyclus fletcheri* E. and H., *Pselophyllum zaphrentiforme* GR., *Cyathophyllum chaoi* GR., *Platyphyllum minor* GR., *Cystiphyllum* cf. *placidum* BARR., *Microplasma poilou* GR., *Stauria cylindrica* YU, *Syringopora* sp., *Eridophyllum* sp., *Pentamerus borealis* EICH., *Conchidium tenuiplicatus* GR., *Glassia obovata* SOW. var. *magna* GR., *Stricklandia transversa* GR., *Stropheodonta* sp., *Trochonema depressa* GR., *Orthonota antelonga* GR. Thickness 62-450 m.

Lower or **Lungma (Fuchih) Shale.** Chiefly dark green shale passing into a graptolitiferous black shale towards the base. Fossils : *Monograptus sedgwicki* PORTL., *M. regularis* TÖRNQ., *M. clingani* CARRUTHERS, *M. crenularis* LAP., *M. marri* PERN., *Rastrites, Orthograptus vesiculosus* NICH., *Petalograptus palmeus* (BARR.), *Glyptograptus incertus* E. and W., *Cephalograptus cometa* (GEINITZ), *Mesograptus chaoi* SUN, *Climacograptus hsichi* SUN, *C. scalaris* HIS., *Favosites nucleolatus* GR., *Heliolites* sp., *Enterolasma* sp., *Coronocephalus rex* GR., *Proëtus latilimbatus* GR., *Bronteus* cf. *partschi* BARR., *Harpes veneulosa* CORD. var. *sinensis* GR., *Illænus asaphoides* GR., *Acidaspis octospinosa* GR., *Glassia obovata* SOW., *Dalmanella testudinaria* DALM., *Triplecia* cf. *grayiæ* DAV. Thickness 400 m.

Pagoda Limestone. Dense limestone with numerous individuals of large *Orthoceras sinensis* FOORD and *Vaginoceras chientzekouensis* YU. Thickness from a few metres to 60 m.

ORDOVICIAN

Neichiashan Series. Greenish-yellow, slabby, argillaceous limestones and shales with *Cycloceras*, *Eccyliopterus sinensis* FRECH, *Vaginoceras duplex* WAHLENB., *Discoceras eurasiaticum* FRECH, *Cameroceras tenuiseptum* HALL var. *ellipticum* YU, *C. hsiehi* YU, *C. subtile* YU, *Vaginoceras neichiaensis* YU, *V. reedi* YU, *V. multiplectoseptatum* YU, *Orthoceras chinensis* FOORD, *O. regulare* SCHLOTH., *O. squamatulum* BARR., *O. yangtzeensis* YU, *Protocycloceras deprati* REED, *Endoceras*, *Cyrtoceras*, *Asaphus hupehensis* SUN and YU, *Taihungshania shui* SUN and YU, *Illænus nanchangensis* SUN and YU, *Bathyurus minor* SUN and YU, *Orthis calligramma* DALM., *O. carausii* SALTER, *O. neichiaensis* CHANG, *O. ellipsoides* CHANG, *Yangtzeella poloi* (MARTELLI), *Clitambonites giraldii* MARTELLI, *Dalmanella* cf. *testudinaria* DALM. and *Didymograptus*. Thickness over 100 m.

Ichang Limestone. Massive limestone, partly thin-bedded, somewhat argillaceous and sandy in the thin-bedded facies. *Callograptus* cf. *salteri* HALL, *Protocameroceras mathieui* GR., *Cameroceras* cf. *styliforme* GR., *Batostomella antiqua* YABE, *Eccyliopterus* sp., *Ophileta*, *Piloceras* and *Orthis* occur in the upper part, and *Archæocyathus* (*Spirocyathus?*) *hupehensis* CHAO, *Girvanella sinensis* YABE in the basal part. Thickness well over 1,000 m.

CAMBRIAN

Luchiapo Sandstone. Grey and yellow micaceous sandstone, sometimes thin-bedded and sometimes thick-bedded. In the middle part of this sandstone *Dorypyge yui* SUN occurs in association with *Obolella* cf. *wirrialpensis* ETH. Thickness about 100 m.

Shipai Shale. Greenish-grey, fissile shale, often sandy and micaceous with lenses and irregular layers of slabby and oolitic limestone containing *Redlichia sinensis* WALCOTT, *Anomocare* and *Obolus*. Thickness 35-200 m.

SINIAN

Tongyin Limestone. Massive white limestone, intercalated at intervals with hard siliceous layers and small, irregular masses of white and black flints. Clusters of cylindrical and conical laminated bodies attributed to *Collenia* occur in the basal part. Thickness 520 m.

Toushantou Series. Thin-bedded limestone and slaty shale passing into a black slaty shale in the lower part with numerous discoid bodies of flint 2 to 3 cm. in diameter. Thickness about 200 m.

Nantou Formation. Tillite in the upper part, red, yellow and white sandstones in the lower part, with occasional layers of red shale and basal conglomerate. Thickness from a few metres to 80 m.

Kunglin Schist invaded by the Huangling granite. The schist is probably of Archæan age, only exposed in the core of the Huangling anticline.

(26) South-Western Szechuan and the Red Basin

Yaun Gravel. Loose gravel with large and small pebbles and boulders up to half a metre across mixed with a yellowish sand and plastic clay. Thickness more than 30 m.

Chiangpei Conglomerate. Coarse conglomerate with well-rounded pebbles of quartzite, black flints and igneous rocks, capping terraces along the tributaries to the Yangtze. Probably Tertiary.

Cretaceous

Kiating Series. Brick-red, friable sandstone, often cross-bedded, occasionally intercalated with layers of clay, visible thickness about 800 m.

Tzuliuching Series. Purple, yellowish and greenish clayey shale with greenish-grey, coarse sandstone, often micaceous, and intercalated, in the Tzuliuching district, with two beds of fresh-water limestone full of *Cyrena*, with some *Unio* and a few teeth of a reptile probably belonging to a crocodile. Thickness estimated at 2,000-3,000 m. in the middle of the basin, but reduced to about 300 m. in its south-western margin. The upper part of this series is named the **Chungking Series** by Heim.

L. Jura. or Rhætic

Hsiangchi Series. White and grey quartzose sandstone, sometimes yellowish, with dark grey shale and thin coal-seams containing *Tæniopteris leclerei* Zeiller, *Neocalamites hoerensis* (Schimper), *N. carreri* Zeiller, *Dictyophyllum nathorsti* Zeiller, *Equisetites* cf. *sarrani* Zeiller, *Cladophlebis* cf. *kamenkensis* Thomas, *Pterophyllum æquale* Nath., *P. propinguum* Schenk, *Podozamites schenki* Heer, *P. lanceolatus* (Lind. and Hutt.), *Pterophyllum multilineatum* Shirley and *Phyllotheca* sp.

Trias

Kialing Limestone. Thick and thin-bedded brittle limestone, light grey in colour, merging downward into a calcareous shale containing beds of rock salt. The uppermost part, which is rather shaly, contains *Halobia comatoides* Yin, *H. omeishanensis* Yin, and *Posidonomya* aff. *wengensis* Wissmann. Thickness about 650 m.

Feisienkuan Series. Purple sandstone and shale or clay intercalated, in the upper part, with impure, grey limestone. Thickness less than 200 m.

Omeishan Basalt. 140-350 m. thick.

Permian

Maokou Limestone. Massive grey limestone sometimes interstratified with dark shale, often highly bituminous, giving off a characteristic odour when struck with a hammer. Nodules of flint are never wanting, but are not numerous. Fossils: *Wentzelella timorica* (Gerth), *Neoschwagerina* sp. near the top; *Cryptospirifer omeishanensis* Huang, *C. striatus* Huang, *C. semiplicatus* Huang, *Martiniopsis omeishanensis* Huang, *Athyris subtriangularis* (Reed), *Schizophoria* sp. in the middle part; *Michelinia microstoma* Yabe and Hayasaka, *Tetrapora* sp. near the base. Thickness about 400 m.

[DEVONIAN]

Hsuimago Formation. Limestones and shales with *Atrypa desquamata* Sow., *Hypothyridina parallelepipeda* (KAYS.), *Chonetes hsuimagoensis* GR., *Orthotetes szechuanensis* GR. in the higher horizon, and *Plectospirifer heimi* GR., *P. subundulata* GR., *Atrypa desquamata* var. *auriculata* HAYAS., *Camarotœchia elliptica* var. *sinensis* GR. in the lower horizon.

[NOTE.—The lower horizon is probably equivalent to the Hwanglienpo (=Hoalingpu) Beds which yield *Columniphyllum loczyi* FRECH, *Haplothecia chinensis* FRECH, *Favosites goldfussi* E. and H., *F. astericus* FRECH, *F. reticulatus* BLAINV., *Alveolites reticulatus* STEINING., *Striatopora clathrata* STEINING., *Chonetes orientalis* LOCZY, *Plectospirifer undifera* (em. GR.), *P. subundulata* (em. GR.), *Camarotœchia elliptica* (SCHNUR), *Camarophoria sutschuanensis* LOCZY, *Gypidula loczyi* (em. GR.), *Cryptonella* cf. *Whidbornii* (DAV.), *Meristella* cf. *tungshanensis* GR.]

[ORDOVICIAN]

Taohengssu Series. Mainly yellowish-grey, quartzitic sandstone and greenish sandy shale with reddish- and purplish-brown quartzose sandstone in the lower part and greenish-grey shale at the top. The latter yields *Taihungshania shui* SUN, *Acidaspis tani* SUN, and *Illænus omeishanensis* SUN. Thickness about 160 m.

Hsihsiangchih Limestone. Grey, impure limestone, calcareous shale and wurmkalk, about 220 m. thick. Age uncertain.

[CAMBRIAN]

Yuhsienssu Series. Grey shale and limestone and yellowish grey quartzitic sandstone. Occasionally oolitic limestone and thin-bedded red sandstone are present at the top. Fossils: *Ptychoparia szechuanensis* SUN, *P. ligea* WALCOTT, *Redlichia nobilis* WALCOTT, *Omeishania yuhsienssuensis* SUN, *Aluta* sp., *Obolella* sp. Thickness 145 m.

Chiulaotung Series. Chocolate-coloured shale, dark grey sandstone with thin beds of limestone near the base. Thickness 230 m.

Sinian Limestone. Light to dark grey, partly crystalline and partly silicified limestone, about 800 m. thick.

Granite.

(27) EASTERN SIKANG

Alluvial sands and **gravels,** sometimes auriferous; thickness up to 200-300 m.

Red sandstone with clays, typically developed at Yulungkou, near Kangting or Tatsienlu; thickness over 100 m., probably Cretaceous.

Kangting Slate. A complex group of shales, sandstones, quartzites and greywackes with occasional thin layers of coal and ill-preserved plant remains of Mesozoic type, probably belonging to the Jurassic. The shales are often altered to slates, phyllites and schists, and sandstones to indurated quartzite. Igneous intrusions and auriferous quartz veins are abundant. Granite and pegmatite abound, being rich in muscovite and huge crystals of tourmaline. Syenite, diorite and gabbro are comparatively rare. The whole area is largely occupied by this formation.

Lihua Shale. Green and purple shale sometimes altered to green schist, occasionally traversed by quartz veins which are usually barren of metalliferous deposit. Probably Triassic. Thickness varies from a few scores to several hundred metres.

Maher Limestone. Limestones or marbles intercalated with green shale or garnet-mica-schist, sometimes containing a white quartzite in the basal part. Permian fusulinids have been found in the limestone, west of Yachou. Thickness up to 1,000 m.

Tampa Series. Mica-schists interstratified with quartzites and granitoid gneisses.

Archæan Gneiss often associated with granite.

(28) South-Eastern Hupeh

TERTIARY

Red clay and **loam** with occasional sandstone and crumbly shale. Thickness varies, usually greater in the low ground, and less towards the hills. Age uncertain.

Red Sandstone. Upper part, mainly red sandstone; lower part, red sandstone and conglomerate with well-rounded pebbles of quartz, black flint and limestone.

CRETACEOUS

Ocheng Volcanic Series. Rhyolite and porphyry sometimes metasomatically replaced by iron ore, *e.g.*, the Linhsiang iron deposit.

Shanpo Series. Yellow, buff, chocolate and greenish-grey shales usually soft and clayey, sometimes sandy with a coarse sandstone in the lower part and an alternation of greenish-grey shale and yellow sandstone forming the base. *Cyrena*, *Corbicula* cf. *anderssoni* Gr., and *Mycetopus mengyinensis* Gr. occur in the basal sandstone and shale.

Jurassic coal-bearing series mainly composed of yellow, grey and greenish-grey, coarse-grained sandstones and conglomerates with greenish-grey shales and thin seams of coal containing *Cladophlebis denticulata* Brongn. and *Podozamites.* Thickness 50-140 m.

TRIAS

Purple shale intercalated with micaceous sandstone, about 500 m. thick.

PERM.

Tayeh Limestone. Light grey and thin-bedded limestone becoming comparatively thick-bedded and more or less silicified in the upper part, and shaly towards the base. Thickness over 500 m.

PERMIAN

Paoan Shale. Sandy shale intercalated with some soft sandstones. *Gastrioceras* (*Girtyites*) *zitteli* GEMM. is the leading fossil.

Tanshanwan Series. Black shales and sandstones with inferior coal-seams in the upper and lower parts and a few beds of limestone yielding *Lyttonia richthofeni* (KAYS.), *Productus gratiosus* WAAGEN, and *Marginifera lopingensis* (KAYS.). Thickness 80 m.

Yangsing Limestone. Upper part, well-bedded limestone occasionally intercalated with layers of carbonaceous shale having a seam of anthracite and some black shales at the base; middle part, dark grey limestone with numerous bands of flint arranged along the bedding planes, like untrimmed mortar between brick courses; lower part, light-grey, lumpy limestone with scattered flints in the upper half, almost free from flints in the lower half. Thickness variable; upper part well over 400 m.; middle part, 200 to 300 m.; lower part much thinner.

SILURIAN

Sintan Formation. Yellow and greenish-grey, fissile shales and sandstones containing *Coronocephalus rex* GR., *Proëtus latilimbata* GR., *Spirifer hsiehi* GR., *Dalmanella, Conchidium* and graptolites in the lower part, which is sometimes separately named the **Fuchih Shale.** Total thickness over 1,000 m.

ORDOVICIAN

Tafan Limestone. Thin-bedded, reddish limestone, some 170 m. thick, forms the upper part, followed downward by a thick-bedded dark limestone attaining a thickness of about 500 m. when fully developed. Thin layers of yellowish earthy limestone and some black carbonaceous shale probably represent the basal part. Fossils are particularly rich in the transitional beds between the reddish, thin-bedded limestone and the dark, thick-bedded limestone. Many cephalopods occur in the thin-bedded limestone or calcareous shales in the upper part, including *Vaginoceras belemnitiforme* HOLM, *V. endocylindricum* YU, *V. uniforme* YU, *V. wahlenbergi* FOORD, *V. peiyangense* YU, *V. shui* YU, *V. neichiaensis* YU, *V. giganteum* YU, *Endoceras leei* YU, *Orthoceras sinensis* FOORD, *O. rudum* YU, *O. suni* YU, *O. elongatum* YU, and *Lituites lii* YU.

(29) NORTH-WESTERN KIANGSI

TERTIARY

Red loam and **clay** with angular boulders and breccia at the base.

Wuming Red Beds. Red clay in the upper part becoming interstratified with gravels and conglomerates in the middle part, and conglomerate at the base, only developed along the valleys.

JURA.

Ifeng Series. Greyish-white sandstone and shale with workable coal-seams and Jurassic plants, typically exposed in the Ifeng district.

PERMIAN

Peishan Limestone. Light grey, thin-bedded limestone containing occasional layers of shale and corals and other fossils in the basal part. Thickness 300-400 m.

Laohushan Series. Yellow shale in the upper part, followed downward by thin beds of flinty limestone rich in brachiopods, then by coal-bearing shales and thinly bedded sandstones; sandstones predominate in the lower part. Total thickness less than 100 m.

Tsoshan Limestone. Dark grey to black limestone with numerous spheroidal flints, corals, brachiopods and fusulinids of the advanced type such as *Neoschwagerina*. *Productus sinensis* FRECH also occurs in this limestone. Thickness variable, 200 m. on the average.

Wangchiapo Series. Black shale with coal-seams of inferior quality and plant remains. Thickness 5 m.

M. CARBON.

Huanglung Limestone. Upper part, white, thick-bedded, close-grained limestone, suitable for lime-burning, containing *Fusulinella bocki* MÖLLER and *Bradyina nautiliformis* MÖLLER; lower part, silicified limestone with closely packed angular fragments of white limestone and red streaks surrounding the fragments. Total thickness about 50 m.

SILURIAN

Yangfuchien Sandstone. Yellowish brown sandstone, barren of fossils; upper part, coarse and thick-bedded hard sandstone; in the lower part, the sandstone becomes softer and interstratified with yellowish-green and grey-green fissile shales which disintegrate into splinters after weathering; upper part about 80 m. thick; lower part about 230 m.

Tengyen Shale. Greenish-grey, buff and white splintery shales, fossiliferous at several horizons. Near the top occur *Encrinurus* (*Coronocephalus*) *rex* GR., *Proëtus* sp., *Dalmanella æquivalvis* (DAV.), *Spirifer hsiehi* GR., *Orthonota antelonga* GR., *Aviculopecten cyheles* BARR. var. *acuta* GR., *Heliolites* sp., etc. In the white, papery shale which forms the basal part, occur *Akidograptus acuminatus* var. *prematurus* DAVIES and *Monograptus tenuis* (PORTLOCK). Total thickness about 530 m.

L. ORDOVICIAN

Wushimen Series. Yellow, grey, purple and black shales interbedded with limestones containing *Didymograptus* cf. *murchisoni* (BECK), *Tetragraptus reclinatus* E. and W., *Dendrograptus* cf. *persculptus* HOPKINS. in the higher horizons, and *Asaphus*, *Illænus* and *Ogygites* in the lower horizons. Thickness about 130 m.

CAMB.

Changyuan Limestone. Dark grey limestone, often thin-bedded and shaly, containing trilobites. Thickness 500-600 m.

SINIAN

Shuangtsiao Series. Divisible into three parts: upper part, sandstones and shales, sometimes carbonaceous, with laminated siliceous beds and a stratum of pebbly clay and sand near the bottom; middle

SINIAN | part, white sandstone; lower part, an alternating series of indurated sandstones and shales, the latter being sometimes hardened to slates and even altered to phyllites. Total thickness more than 1,500 m.

(30) LUSHAN AREA, NORTHERN KIANGSI

PLEISTOCENE?

Siashu Loam. Homogeneous, buff, sandy clay covering hill-tops. Thickness varying from a veneer to 20 m.

Mottled Clay. Tough, red clay often mottled with numerous white patches and streaks arranged in all fashions, sometimes slightly lateritized. Thickness up to 18 m.

Lushan Boulder Beds. Tenacious red clay mixed with transported sub-angular boulders, entirely unstratified and sometimes slightly lateritized. Associated with this boulder-and-clay deposit are gravel beds of uncertain relation. Thickness up to 12 m.

TERT.

Red Sandstone. Well-bedded, rather soft red sandstone exposed near the shore of the Poyang Lake.

URALIAN

Chuanshan Limestone. Dark grey to black limestone with streaks of red, containing characteristic fusulinids of the Chuanshan Stage. Thickness about 25 m.

M. CARB.

Huanglung Limestone. Light grey, close-grained pure limestone, thickly bedded, with *Fusulinella bocki* MÖLLER. Thickness over 50 m.

SIL.

Tungyuan Series. Yellow to greenish-yellow shales and buff sandstones with *Spirifer hsiehi* GR.

M. ORD.

Niutoushan Limestone. Dark, hard limestone with *Orthoceras sinensis* FOORD. Associated with this limestone occasionally occur limestones showing alternating white and blue bands and carbonaceous shale.

CAMBRIAN

Kuanyintang Series. Laminated blue limestones and chocolate-coloured shales in the upper part, greenish-grey shales with *Redlichia sinensis* WALCOTT in the lower part.

SINIAN

Matsu Limestone. Black limestone thoroughly silicified and often laminated. Thickness over 80 m.

Yangchiawan Series. Black, carbonaceous shale full of calcite veins with brown sandstone in the upper part, finely laminated, red and reddish-yellow micaceous sandstones in the lower part, and a red clay near the base. Thickness about 200 m.

SINIAN

Kunluling Series. Bluish-white, greenish and silver grey, clayey slates with laminated micaceous sandstones in the upper part, and loose or crumbly, ashy-grey sandstones marked by numerous inconstant layers, lenses and streaks of black material in the lower part. A hard, conglomeratic sandstone (20 m. thick) is intercalated in the lower part, and a yellowish to buff, quartzose, soft sandstone forms the base. Total thickness about 360 m.

Wulaofeng Grit. Coarse, well-bedded, quartzose grit with large and rounded grains of bluish quartz. Between the individual beds of the grit often occurs a thin layer of slaty shale. Ripple-marks and false-bedding are fairly common. Thickness 800 m.

Niangtienping Shale. Yellow to greenish-yellow shales passing into a fine-grained sandstone in the lower part. Thickness about 120 m.

WUTAI

Lushan Group. Slates, phyllites, schistose and micaceous sandstones, hornblende-schist and mica-garnet-schist forming the bulk of the southern part of the Lushan. Total thickness about 2,600 m.

Nankang Granite.

(31) NORTH-EASTERN KIANGSI

Red Beds. Red and purple sandstones, shales and conglomerates. Shales and soft sandstones predominate in the upper part; conglomerates abound in the lower part. Thickness over 430 m. Age: Upper Cretaceous or early Tertiary.

CRETACEOUS

Wuyi Series. Upper part, porphyritic rhyolite with large phenocrysts of felspar, considerable in thickness, followed downward by quartz porphyry and then by purple sandstone and shale; middle part, conglomerate, tuffaceous sandstone, and thin-bedded rhyolite, fine in texture; lower part, trachyte and andesite. Thickness more than 1,000 m.

Chinglung Limestone. Light grey, siliceous (?) limestone, always thinly stratified, an individual bed rarely exceeding 3 cm. in thickness. Thickness about 100 m. Probably Triassic.

PERMIAN

Loping Series. Brownish and yellowish sandstones and coal-bearing shales with occasional marly limestones and marine shales intercalated in the coal-bearing beds, a reddish or yellow sandstone or sandy shale at the top and a massive sandstone and conglomerate at the base. *Gigantopteris nicotianæfolia* SCHENK, *Pecopteris anderssoni* HALLE, *Alethopteris norini* HALLE and *Tæniopteris latecostata* HALLE occur in the coal-bearing shales, and *Lyttonia richthofeni* (KAYS.), *Martinia triquetra* GEMM. var. *lopingensis* GR., *Richthofenia laurenciana* WAAGEN, *Enteletes kayseri* WAAGEN, *Reticularia waageni*

PERMIAN

LOCZY, *R. indica* WAAGEN, *Productus kiangsiensis* KAYS., *Marginifera lopingensis* KAYS., *Derbyia grandis* WAAGEN, *Orthotetes* cf. *eusarcus* ABICH, and *Phillipsia obtusicauda* KAYS. in the marine beds. Thickness 580 m. at the maximum, but usually less.

Chihsia Limestone. Massive, grey limestone, often silicified in the upper part, with nodules or bands of chert arranged along the bedding planes. Black, siliceous shale or chert, sandy shale, and bands of cherty limestone form the uppermost part. Brachiopods abound. Thickness 220 m. or more.

Mengshan Series. Reddish shales and quartzites of considerable thickness. Lower Carboniferous or Silurian.

Tsintsun Series. Greenish-grey calcareous shale interstratified with fine sandstone of brownish colour. Probably Silurian, but possibly belonging to the Ordovician.

ORDOVICIAN

Tananling Limestone. Whitish-grey, siliceous limestone interstratified with brownish-yellow shale. *Orthograptus rugosus, O. truncatus* LAPW., and *Mesograptus foliaceus* MURCHISON occur in the upper part, and *Tetragraptus bigsbyi* HALL, *Didymograptus extensus* HALL, and *Trigonograptus ensiformis* HALL in the lower part. Thickness 300 m.

Yushan Shale. Mainly lustrous shale, often greenish in colour, with occasional thin beds of sandstone, becoming somewhat calcareous in the upper part and including one or two beds of limestone. Graptolites occur in several horizons. The leading species are: *Phyllograptus anna* HALL, *P. ilicifolius* HALL, *P. angustifolius* HALL, *Tetragraptus bigsbyi* HALL, *Didymograptus extensus* HALL, *D. hirundo* SALTER, *D. nicholsoni* LAPW., *Trigonograptus ensiformis* HALL, *Dichograptus separatus* ELLES. Thickness 450 m.

Chaotang Series. Upper part, light grey limestone interstratified with purple and dark grey clay-shale, about 80 m. thick; middle part, thin-bedded sandstone, orange-yellow in colour, 175 m. thick; lower part, highly bituminous slaty shale, rich in iron pyrites, often used as fuel for lime-burning, 100 m. thick. Total thickness exposed 355 m.

(32) SOUTH-WESTERN KIANGSI

Red Clay.

Red Beds. Red sandstones and shales in the upper part and conglomerate in the lower part. Probably Tertiary.

JURA.

Tienho Series. Coal-bearing shales with Jurassic plants in the middle and quartzose sandstones in the upper and lower parts.

PERMIAN

Fengtien Series. Shales and sandstones containing five or more coal-seams. The shales and sandstones contain marine fossils as well as plants. Among the marine fossils are *Reticularia* cf. *lineata* Martin, *Enteletes magniventra* Gr., *Productus* cf. *mytiloides* Waag., *Glyphioceras (Anderssonoceras) anfuense* Gr., *Girtyites liui* Gr., and *G. zitteli* (Gemm.), and the flora includes *Gigantopteris*. Thickness 200 m.

Hsiaochiang Limestone. Black, impure limestone, sometimes white and cherty. Fossils are *Productus semireticulatus* Martin, *P. gratiosus* Waagen, *P. rhynchonelloides* Chao, *P. chianensis* Chao, *P. alternopustulosus* Chao, *P. cora* d'Orb., *Schizophoria chianensis* Gr., *Orthotichia morganiana* Derby var. *sinensis* Gr., *Orthotetes tingi* Gr., *O. anderssoni* Gr., *O. carinostriata* Gr., *Spiriferina chuchuani* Gr., *Reticularia lineata* Mart. Thickness 40 m.

Aocheng Series. Shales and sandstones, with several coal-seams, and sometimes with iron-ore in the upper sandstones. Plant remains also occur. Thickness 140 m.

Yunghsin Group. Upper part, red shales and sandstones, often micaceous, becoming quartzose towards the top; middle part, black shale with thin seams of coal and white limestone; lower part, metamorphosed sandstones and phyllitic shales. Extensively exposed in the Yunghsin and Chihan districts.

(33) South-Eastern Kiangsi

TERTIARY

Hangpu Series. Red and grey, thin-bedded, soft sandstones intercalated with red and grey clays, gravels or conglomerates. Thickness 20-100 m.

CRET.?

Nancheng Sandstone. Red and thick-bedded, coarse sandstone, often conglomeratic, with occasional layers of grey and reddish shales, forming hill-ranges near Nancheng. Thickness at least 500 m.

JURASSIC

Yungshan Sandstone. Coarse, white sandstone interbedded with reddish-brown and greenish-grey shales; about 200 m. thick.

Tsungjen Series. White and greenish-grey, coarse sandstones becoming quartzitic in certain facies, intercalated with coal-bearing shales containing Jurassic plants and occasional conglomerates. Thickness over 1,000 m.

Lipichiao Series. Grey and black shales interstratified with well-bedded grey sandstone containing thin seams of coal and Jurassic plants. Thickness about 400 m.

PERMIAN

Luoling Sandstone. White quartzose sandstone with red and greyish clays and occasional layers of shale, 200-300 m. thick.

Chunglingchiao Limestone. Grey to black, pure limestone with lenticular bodies of flint. Thickness 100 m.

WUTAI OF CARBONIFEROUS

Chinhsien Series. Quartzitic sandstone intercalated with silver-grey shales and sandstones in the middle part in which occur irregular seams of coal. Several species of *Neuropteris*, including *N. inflata* LESQX. and *N. scheuchzeri* HOFFM., have been found in black and greenish-yellow shales. Thickness probably more than 1,000 m.

SINIAN

Linchuan Series. Mica- and chlorite-schists, phyllites and quartzites cut by numerous quartz veins and dykes of porphyry. Thin layers of graphite occur in the mica-schist. Thickness over 500 m.

ARCH.

Shakuan Complex. Chiefly gneissic rocks often invaded by intrusions of granite.

(34) SOUTHERN ANHUI

Reddish Loam with occasional pockets of gravel.

Mottled Red Clay.

Red Clay with boulders and gravel beds.

Red Sandstone interstratified with sandy clays and conglomerates, the latter prevailing in the lower part. This sandstone is sometimes named the **Hsuannan Sandstone,** and the conglomerate the **Tatung Conglomerate.** Thickness about 120 m. on the average. Probably early Tertiary.

Shihtih Series. Rhyolite in the upper part, tuffs, red sandstones and conglomerates in the lower part. Thickness 150-300 m. Cretaceous.

Tungkuan Series. Altered shales and sandstones with plant remains and a seam of coal; only developed in the region close to the Wuyi Range. Thickness about 500 m. Probably Jurassic.

PERMIAN

Chinglung Limestone. Generally thin-bedded limestone with thick beds in the upper part, usually buff in colour. A pale reddish stratum persists in the upper part. Calcareous shales sometimes occur at the base. Thickness 400-500 m.

Changhsin Limestone? Dark carbonaceous limestone and shale with fossils near the base, including *Oldhamina?* Thickness 150 m.

Hsuanchin Series. Grey sandstones, carbonaceous shales and black, shaly limestones containing several seams of coal. *Lyttonia richthofeni* (KAYS.), *Spinomarginifera lopingensis* (KAYS.), *Productus* cf. *gratiosus* WAAGEN, *P. intermedius* var. *sinensis* FRECH, *P. kiangsiensis* CHAO, *Girtyoceras liui* GRABAU and *Glyphioceras* (*Anderssonoceras*) *anfuense* GR. occur in the marine beds, and *Gigantopteris nicotianæfolia* SCHENK, *Neuropteris* sp. and *Tæniopteris* sp. in the land facies. Thickness 50-100 m.

PERMIAN

Kuhfeng Series. Variable in facies-development: sometimes represented by thick-bedded, dark grey limestone with numerous concretions of flint and sometimes by black shales or even purplish sandy shale and mudstones yielding numerous *Gastrioceras*, a few specimens of *Euomphalus* and *Orthotetes*, and rarely individuals of *Griffithides* cf. *obtusicauda* KAYS. Thickness 0-80 m.

Chihsia Limestone. Dark blue to black limestone, often thick-bedded, with bands of flint arranged along the bedding planes, becoming highly bituminous and impure towards the basal part. In places this impure limestone is replaced by a thin shale with a seam of inferior coal. Fossils in the massive limestone: *Nankinella orbicularia* LEE, *Pseudofusulina chihsiaensis* LEE, *Tetrapora nankingensis* YOH, *T. laxa* YOH, *T. elegantula* YABE and HAYAS., *Michelinia marginocystosa* HUANG, *Monilopora dendroides* YOH, *Polythecalis multicystosis* HUANG, *P. yangtzeensis* var. *hochowensis* HUANG, *Lophophyllum pendulum* var. *simplex* HUANG, *Allotropiophyllum* cf. *sinensis* GR. Thickness 70-220 m.

Chuanshan Limestone. Light grey and brittle limestone, often globulitic in structure with *Schwagerina princeps* EHRENB., *Pseudofusulina prisca* (EHRENB.), *P. vulgaris* var. *watanabei* LEE, and other fusulinids of the Uralian Stage. Thickness 10-20 m.

M. CARBON.

Huanglung Limestone. White or flesh-coloured limestone, exceedingly pure, but sometimes lumpy in appearance with *Fusulinella bocki* MÖLLER. Basal part usually much harder, slightly greenish in colour and siliceous in composition, barren of fossils. Thickness 20-74 m.

L. CARBON.

Kaolih Series. Purplish shales interstratified with sandstones containing indeterminable plant remains. Thickness 10-40 m.

Wutung Sandstone. Buff, purplish and white sandstones, usually coarse, and sometimes conglomeratic, with interbedded shales containing *Lepidodendron* and *Calamites*. Thickness up to 400 m. Lower Carboniferous.

SILURIAN

Kaochiapien Shale. Dark green sandstone and shales in the upper part with *Coronocephalus rex* GR., greenish shales and thin-bedded sandstones in the middle, and buff and light grey shales with occasional limestones in the lower part. A black shale is sometimes present at the base. The light grey shale contains *Monograptus acinaces* TÖRNQ., *M. kueichihensis* HSU, *Climacograptus hughesi* NICH., *C. scalaris* var. *normalis* LAPW., *C. yangtzeensis* HSU, *Orthograptus mutabilis* E. and W., and *Glyptograptus tamariscus* NICH. The black shale contains *Monograptus latus* McCOY. Thickness 1,200-1,500 m.

Hulo Shale. Whitish sandy shale and brownish shale with siliceous bands in the upper part, about 40 m. thick, containing *Dicellograptus sextans* E. and W., *Glossograptus hincksii* HOPKINSON, *Trigonograptus lineatus* HSU, *Climacograptus latus* E. and W., *C. scharenbergi* LAPW., *C. pusillus* (HALL) var. *eximius* RUEDEMANN, *C. forticaudatus* HSU, *C. uniformis* HSU, *Dicranograptus ziczac* LAPW., *Didymograptus spinosus* var. *flexilis* HSU, *Cryptograptus tricornis* (CARRUTHERS), and *Orthograptus pageanus* var.; yellowish clay-shale in the lower part yielding *Dicranograptus nicholsoni* var. *diapason* GURLEY, *D. furcatus* (HALL), *Dicellograptus smithi* RUEDEM., and *D. divaricatus* HALL.

ORDOVICIAN

Ningkuo Shale. Greenish, bluish and brownish shale, containing *Didymograptus hirundo* SALTER, *D. abnormis* HSU, *D. gibberulus* NICHOLSON, *D. nitidus* (HALL), *D. acutidens* E. and W., *D. ellesi* (RUEDEM.), *D. spinosus* RUEDEM., *Tetragraptus bigsbyi* (HALL), *Phyllograptus anna* HALL, *P. ilicifolius* HALL, *P. curvithecatus* HSU, *P. angustifolius* HALL, *Trigonograptus ensiformis* HALL, *Glyptograptus dentatus* BRONG., *Climacograptus forticaudatus* HSU, and *C. uniformis* HSU. Thickness 90 m.

Tanchiachiao Series. Upper part: greenish-yellow shales, somewhat calcareous. Middle part: purplish-red mudstones alternating with greenish calcareous shales. Lower part: bluish-grey calcareous shales becoming more calcareous towards the base. *Clonograptus tellenus* var. *callavei* LAPW. and *Asaphus ovatus* SHENG occur throughout the series. Total thickness about 230 m. Well exposed in the Taiping and Lantien districts.

SINIAN

Hiuning Series. Grey limestones in the upper part, some 300-400 m. thick, followed down by interbedded calcareous and carbonaceous shales and thin limestones. This is in turn followed by a well-laminated siliceous rock with alternating white and black layers, each 2 or 3 cm. in thickness. The total thickness of these siliceous beds reaches 80 m. Then follows a series of black limestones intercalated with black shales which are often highly carbonaceous. Total thickness over 600 m.

Lantien Tillite? Fine-textured, bluish-grey shaly rock with large and small pebbles of granite and other rocks of distant origin. These, together with sands, are usually chaotically mixed with the fine shale. Locally, however, the sands and gravels show a rude stratification. Thickness 5-10 m.

Pihyuan Sandstone. Green and purple sandstones with a thick conglomerate at the base. Total thickness over 12,000 m.

Shangchi Formation. Upper part, pale green calcareous shale or phyllite, breaking into hackly slabs, interstratified with quartzites; lower part, bedded green schists with quartzites. Total thickness more than 2,000 m. Probably Upper Wutai.

(35) Nanking Hills

Siashu Loam. Reddish sandy clay with limy concretions scattered throughout the formation. Land and fresh-water shells such as *Traumatophora, Eulota, Ganesella, Buliminus, Opeas* and *Cyclophorus* are found in the middle part of the deposit. Thickness 10-30 m.

Basalt. Mesa basalt, full of amygdaloids and vesicles, which are often coated internally with a film of cobalt oxide, or filled up with zeolites. Thickness 50-100 m.

Yuhuatai Beds. Gravels, ill-bedded red and yellow sandstones, marls, laminated bluish clays and fresh-water limestone containing pelecypods, gastropods, particularly the genus *Bithynia,* and fish scales or spines. Sheets of basalt are occasionally intercalated in the upper part of the formation. Thickness variable.

Chihshan Sandstone. Soft sandstone, well-bedded and bright red in colour with a gravelly bed at the base. Thickness 60 m.

Pukow Formation. Dark red sandstone and conglomerate often intercalated with sandy shale. Conglomerate prevails in the lower part. Probably early Tertiary. Thickness about 400 m.

Cretaceous

Tuff Series. Andesite and rhyolite in the upper part, tuffaceous conglomerate, agglomerate and volcanic ash in the lower part. Thickness about 200 m.

Estheria Beds. Soft shales containing *Cyrena hsiangchiensis* Chao, *Estheria* and *Podozamites.*

Jurassic

Hsiangshan Series. Coarse sandstones, sandy shales and clay-shales bearing coal-seams near the base. A moderately coarse conglomerate often forms the very base. Plants are found in several horizons, including *Baiera gulihaumati* Zeiller, *Pagiophyllum* aff. *peregrinum* L. and H., *Podozamites lanceolatus* (L. and H.), *Pterophyllum* cf. *æquale* Brongn., *Cladophlebis* sp., *Otozamites* sp., *Equisetites* sp., *Neocalamites* sp., and *Dictyophyllum* sp. Fresh-water shells, such as *Cyrena hsiangchiensis* Chao, are sometimes associated with the plant-bearing beds. Thickness about 800 m.

Triassic

Huangmaching Series. Upper part, dirty green argillaceous sandstone interstratified with yellow shale, about 40 m. thick; middle part, an alternation of sandy shales and sandstones predominantly purplish in colour, less than 600 m. thick; lower part, purple, buff and dark grey sandstones with local coal-seams and conglomerates at the base. *Cladophlebis haiburnensis* (L. and H.), *Tæniopteris* sp., *Macrotænio-pteris crassinervis* FEISTM., *Podozamites lanceolatus* (L. and H.), and *Dictyophyllum nilssoni* BRONGN. occur in the coal-bearing shales. Total thickness 500-650 m.

TRIASSIC

Chinglung Limestone. Upper part, laminated limestone divided into thick strata, generally grey in colour, but occasionally reddish, about 200 m. thick; middle part, thin-bedded limestone interstratified with yellow calcareous shales and marls yielding indistinct impressions of *Ophiceras, Xenodiscus, Kashmirites* and *Terebratula;* lower part, interbedded calcareous shales and thin-bedded limestones containing the *Otoceras* fauna. About 200 m. thick.

U. PERMIAN

Tungyangkang Series. Thin-bedded siliceous limestones with black flinty layers frequently appearing between the more calcareous layers. Thickness 120 m. at Tungyangkang, south-east of the Tsao-fengshan. Elsewhere in the Nanking Hills this series is generally absent.

Lungtan Series. Sandstones and coal-bearing shales yielding *Gigantopteris nicotianæfolia* SCHENK, *Rhizomopsis gemmifera* GOTHAN and SZE, *Protoblechnum wongi* HALLE, and *Annularia elliptica* GOTHAN and SZE. With the sandstones and shales are usually interstratified beds of impure bituminous limestone which contains *Productus (Marginifera) lopingensis* KAYS., *Lyttonia* cf. *nobilis* WAAGEN, and *Spino-marginifera* cf. *kueichouensis* HUANG. Thickness 30-50 m.

L. PERMIAN

Kuhfeng Formation. Sandy and calcareous shale, easily weathered to a reddish brown or purplish colour; with *Gastrioceras zitteli* GEMM., *Girtyoceras liui* (GR.) and *Lyttonia* cf. *richthofeni* (KAYS.). Thickness 15 m. or less, sometimes absent.

Chihsia Limestone. Usually divided into four parts arranged in descending order as follows :—

(4) **Upper Lydianite.** Black siliceous shales and impure lime-stones with numerous flints. Fossils: *Polythecalis multicystosis* HUANG, *P. chinensis* (GIRTY), *Parafusulina multiseptata* (SCHELLW.), *Productus (Marginifera) obscura* CHAO.

(3) **Tetrapora Beds.** Dark grey to black limestone, often thick-bedded, with numerous flints arranged in bands along the bedding planes. Fossils as collected in three horizons are as follows :—

Upper: *Polythecalis chinensis* (GIRTY), *P. yangtzeensis* HUANG, *Michelinia multisepta* HUANG, *Tetrapora nankingensis* YOH, *Pseudo-fusulina chihsiaensis* (LEE), *Parafusulina undulata* CHEN, *P. multi-septata* (SCHELLW.), ? *Verbeekina verbeeki* GEINITZ, *Productus nanking-ensis* FRECH, *Lyttonia* cf. *nobilis* WAAGEN.

Middle: *Tetrapora elegantula* YABE and HAYAS., *T. nankingensis* YOH, *Allotropiophyllum sinensis* GR., *Michelinia siyangensis* REED,

LOWER PERMIAN

Polythecalis chinensis (GIRTY), *Nankinella orbicularia* LEE, *Eoverbeekina intermedia* LEE, *Kiangsiella pectiniformis* var. *nankingensis* GR., *Schuchertella* cf. *semiplana* (WAAGEN).

Lower: *Stylidophyllum volzi* (YABE and HAYAS.), *Corwenia chihsiaensis* YOH, *Yatsengia asiatica* HUANG, *Tetrapora nankingensis* YOH, *Michelinia multicystosa* YOH, *Monilopora dendroides* YOH, *Pisolina excessa* LEE.

(2) **Lower Lydianite.** Black, siliceous shale with numerous flints with *Stylidophyllum volzi*. Thickness a few metres to 10 m.

(1) **Swine Limestone.** Highly bituminous limestone, usually thin-bedded and more or less argillaceous, giving off an offensive odour at a blow of the hammer. Fossils: *Michelinia* cf. *multisepta* HUANG, *Schubertella pseudobscura* CHEN, *Triticites pseudocontracta* CHEN, *Pseudofusulina vulgaris* var. *watanabei* (LEE), *Doliolina claudiæ* DEPRAT, *Pseudofusulina gregaria* (LEE), *P. tschernyschewi* (SCHELLW.), *Parafusulina japonica?*, *Triticites parvus* (LEE), and *T. kwanshanensis* CHEN.

Total thickness 110-150 m.

URALIAN

Chuanshan Limestone. Light grey and bluish limestone often mixed in one and the same stratum, usually thick-bedded, traversed by irregular joints and cracks which are filled with streaks of red material. Globulitic structure common; fragments of shell and worn foraminiferal tests occur in masses suggesting petrified foraminiferal sand. Basal conglomerate sometimes present. *Schwagerina princeps* EHRENB. forms a whole bed at the top of the limestone, though it occurs in lower horizons as well. The other leading species of foraminifera are: *Pseudofusulina prisca* EHRENB., *P. alpina* (SCHELLW.), *P. vulgaris* (SCHELLW.), *Quasifusulina longissima* (MÖLLER), *Schwagerina fusulinoides* (SCHELLW.), *Triticites pusillus* (SCHELLW.), *T. regularis* (SCHELLW.), *T. contractus* (SCHELLW.), and *T. simplex* (SCHELLW.). Thickness 10-30 m.

M. CARBONIFEROUS

Huanglung Limestone. Pinkish or white limestone, exceedingly pure in quality, extensively used for lime-burning and cement-making, assuming a brecciated appearance and embodying a mosaic of large crystals of calcite towards the lower part, with a dense, slightly greenish and apparently silicified limestone forming the base. Fossils: *Fusulina cylindrica* FISCHER, *F. quasicylindrica* LEE, *F. lanceolata* LEE and CHEN, *F. schellwieni* STAFF, *Fusulinella chuanshanensis* LEE and CHEN, *F. colanii* LEE and CHEN, *F. subrhomboidalis* LEE and CHEN, *F. schwagerinoides* (DEPRAT), *F. laxa* LEE and CHEN, *F. bocki* MÖLLER, *F. pseudobocki* LEE and CHEN, *F. parva* LEE and CHEN, *Fusiella typica* LEE and CHEN, *F. paradoxa* LEE and CHEN, *Schubertella obscura* LEE and CHEN, *S. magna* LEE and CHEN, *Staffella ozawai* LEE and CHEN, *S. sphæroidea* (MÖLLER), *Bradyina nautiliformis*

M. CARBONIFEROUS

MÖLLER, *Cribrostomum antiqua* BRADY, *C. stiliforme* LEE and CHEN, *C. eximium* EICHW., *C. longissimoides* LEE and CHEN, *C. maximum* LEE and CHEN, *C. nelumboforme* LEE and CHEN, *C. infundibulum* LEE and CHEN, *C. elegans* MÖLLER, *Tetrataxis conica* EHRENB., *Chætetes lungtanensis* LEE and CHU, *C. varitabularis* LEE and CHU, *Multithecopora huanglungensis* LEE and CHU, *Siphonodendron reticulatum* LEE and CHU, *Orionastræa asiatica* YU, *Enteletes lamarcki* FISCHER, *Choristites* cf. *mosquensis* FISCHER. Thickness 100 m.

LOWER CARBONIFEROUS

Hochou Limestone. Thin-bedded argillaceous limestone becoming shaly towards the lower part. The limestones in the upper part are full of foraminifera, particularly the genera *Endothyra* and *Orobias*. *Gigantella giganteus* (MARTIN), *Yuanophyllum kansuensis* YU, *Siphonodendron irregulare* PHILL. and *Lithostrotion portlocki* (BRONN) are among the other leading forms. Thickness a few metres to 11 m.

Kaolih Series. Sandstones and shales of yellowish-green or purple colour, with a few thick beds of quartzite and lenticular layers of earthy yellow limestone. Fossils: *Lepidodendron mirabile* (NATHORST) GOTHAN, *Lepidostrobus ungulatus* GOTHAN and SZE, *Lepidodendron* cf. *leeianum* GOTHAN and SZE, *Sphenophyllum* sp., *Stigmaria ficoides*?. Thickness 15-50 m.

Kinling Limestone. Dense and dark limestone, partly slabby and shaly, containing *Syringopora subramulosa* CHU, *Michelinia æqualis* CHU, *M. kiangnanensis* CHU, *Pseudouralinia tangpakouensis* YU var. *kiangsuensis* CHU, *P. kaolishanensis* CHU, *P. kayserlingophylloidea* CHU, *P. nankingensis* CHU, *Eochoristites neipentaiensis* CHU, *E. leei* CHU, *E. elongata* CHU, *Martiniella chinglungensis* CHU, *Rhipidomella michelini* L'EVEILLÉ var. *minor* GR., *Productus kinlingensis* CHU, *Athyris submembranacea* GR., *Schellwienella crenistria* (PHILL.), *Platyceras* sp., *Bellerophon* sp., and *Phillipsia* sp. Thickness 4-6 m.

Wutung Series. Upper part, whitish clay and shales intercalated with buff or whitish quartzites containing *Lepidodendron leeianum* GOTHAN and SZE, *L. procurrens* GOTHAN and SZE, *Lepidophyllum xiphidium* GOTHAN and SZE, *L.* cf. *mirabile* NATHORST, *Sphenophyllum lungtanensis* GOTHAN and SZE, *Knorria* sp., and *Neuropteris* sp.; lower part, dark red or purplish quartzite with light grey sandstones at the base. Thickness 200-300 m.

SILURIAN

Kaochiapien Series. Greenish and yellowish shales and shaly sandstones, often micaceous, with a black, siliceous shale and whitish clay at the base. Graptolites abound in several horizons. At an horizon about 1,000 m. from the base occur *Monograptus nankingensis* HSU, *M. acinaces* TÖRNQ., *M. argutus* LAPW., *M. atavus* JONES, *M. concinnus* LAPW., *M.* cf. *griestoniensis* (NICH.), *M. leei* HSU, *Glyptograptus lunshanensis* HSU, *G. tamaricus* NICH., and *Climacograptus yangtzeensis* HSU. At an horizon about 400 m. from the base occur

SILURIAN

Monograptus leei Hsu, *M. revolutus* Kurck, *M. regularis* Törnq., *M. atavus* Jones, *Akidograptus priscus* Hsu, *Climacograptus hughesi* (Nich.), *C. scalaris* var. *normalis* Lapw., and *Glyptograptus tamariscus* Nich. The basal part contains *Mesograptus modestus* Lapw., *Akidograptus ascensus* Davies, *Climacograptus scalaris* var. *miserabilis* E. and W., *C. minutus* Carruthers, *Glyptograptus kaochiapienensis* Hsu, and *Orthograptus tumidicaulus* Hsu. Thickness 1,200-1,300 m.

ORDOVICIAN

Tangshan Series. Shales and earthy limestones of buff or pale red colour, sometimes silicified, yielding *Vaginoceras* aff. *uniforme* Yu, *Orthoceras sinensis* Foord, *Endoceras duplex* (Wahlenberg), *Clitambonites* (*Orthisinia*) *squamata* (Wahlen.), *Orthis* cf. *calligramma* Dalm., *Eccyliopterus* (*Raphistoma*) *sinensis* Frech. Thickness 30-40 m.

Lunshan Limestone. Upper part, light grey limestone with a few flints becoming shaly and earthy towards the top, containing *Camerоceras hupehense* Yu, and *Suecoceras attenuatum* Gr.; middle part, whitish grey or pale red limestone, with thick and thin beds alternating, often silicified, containing many flints; lower part, thick and thin-bedded limestone with flints and siliceous bands. Total thickness over 900 m. Middle and lower parts possibly Sinian.

Huangshu Series. Dark grey slates and thin-bedded argillaceous limestone, occasionally silicified, passing downwards into buff slates or phyllites interstratified with calcareous shales. Coaly shales usually present in the middle part of this series. Visible thickness over 300 m.

(36) North-Western Chekiang

Mottled Red Clay.

Tsientang Conglomerate. Coarse conglomerate, almost unstratified, well-developed in the lower Tsientang Valley. Thickness up to 30 m.

Red Sandstone. Probably of Tertiary age.

CRETACEOUS

Tienmong Rhyolite. Bright green, purplish-red and dark-brown rhyolite showing fluidal structure and containing large phenocrysts of quartz and felspar. Purplish-red and dark brown varieties predominate. Total thickness about 1,000 m.

Tzaochih Conglomerate. Coarse conglomerate almost entirely composed of pebbles of rhyolite.

Kuhshan Series. Purple rhyolite intercalated with whitish and purplish tuff, often rich in biotite.

Painiuchen Sandstone. Purple, fine-grained hard sandstone with scattered fragments of limestones, flints and agate in some layers and with a conglomerate at the base.

TRIAS.

Chinglung Limestone. Light grey or white, thin-bedded limestone, sometimes argillaceous, and not infrequently ferruginous, bedding often undulatory or even contorted. Thickness 400 m.

PERMIAN

Changhsin Limestone. Dark grey to black limestone often laminated, with small concretionary bodies of flint, containing *Oldhamina decipiens* (DE KONINCK), *Reticularia waageni* LOCZY, *R. inæquilateralis* GEMM., *Squamularia waageni* (LOCZY), *Productus gratiosus* WAAGEN, *P. yangtzeensis* CHAO, *P. mongolicus* DIENER, *Pustula abichi* (WAAGEN), *Linoproductus mongolicus* (DIENER), *Spinomarginifera lopingensis* (KAYSER), *Ortholetes* cf. *eusarcus* ABICH, *Parenteletes sinensis* HUANG, and *Tachylasma aster* GR. Thickness 20 m.

Lungtan Series. Soft sandstones, shales and coal-seams yielding *Gigantopteris nicotianæfolia* SCHENK, *Sphenopteris* cf. *grabaui* HALLE, *Tæniopteris tingi* HALLE, *Pecopteris*, *Neuropteris*, *Sphenophyllum* and *Calamites*. Thickness 300 m.

Kuhfeng Formation. Siliceous shales and soft argillaceous sandstones, about 10 m. thick.

Nankaofeng Limestone. Dark blue limestone with *Verbeekina verbeeki* (GEINITZ), *V. minor* CHEN, *Pseudodoliolina ozawai* YABE and HANZAWA, and *Cancellina schellwieni* DEPRAT.

Chihsia Limestone. Upper part, dark grey limestone, about 100 m. thick, containing *Parafusulina multiseptata* (SCHELLWIEN), *P. subextensa* CHEN, *Nankinella orbicularia* LEE, *Pseudofusulina chihsiaensis* LEE, *Corwenia chiuyaoshanensis* HUANG, *Bradyphyllum caninoides* HUANG, *Productus yangtzeenis* var. and *Athyris bicincta* GR. Lower part, bituminous and siliceous limestone, about 40 m. thick, containing *Schubertella pseudobscura* CHEN, *S. regularis* CHEN, *Triticites kiupaostanensis* CHEN, *T. pusillus* (SCHELLWIEN), *T. bellus* CHEN, *Parafusulina japonica* (GÜMBEL), *Pseudofusulina vulgaris* var., *P. gregaria* LEE, *Polythecalis yangtzeensis* HUANG and *P. chinensis* (GIRTY).

URALIAN

Chuanshan Limestone. Dark grey and carmine limestones, often globulitic, and weathered out into fantastic shapes, extensively used for rockery art, containing *Triticites simplex* (SCHELLWIEN), *T. minimus* (SCHELL.), *T. contractus* (SCHELL.), *T. parvulus* (SCHELL.), *Pseudofusulina prisca* (EHRENBERG), *P. vulgaris* (SCHELL.), *P. alpina* (SCHELL.), *P. vulgaris* (SCHELL.) var., and *Schwagerina princeps* (EHRENBERG). Thickness about 30 m.

M. CARB.

Huanglung Limestone. Light grey or pink, fine-textured limestone with *Fusulina cylindrica* FISCHER, *Fusulinella bocki* MÖLLER, *Orobias ozawai* LEE and CHEN, *Chætetes lungtanensis* LEE and CHU, and *Caninia simplisepta* CHI. Thickness 40 m.

Kaolih Shale. Dark grey sandstone and purple shale with layers of earthy limestone, about 40 m. thick.

L. CARB.

Wutung Quartzite. Buff and sometimes purplish quartzose sandstone and quartzite intercalated with plant-bearing sandy shales, siliceous layers and occasional conglomerate. Thickness 300-400 m.

Tangchiawu Sandstone. Hard, coarse sandstone, dark green and sometimes dark brown in colour, more than 500 m. thick. Age undetermined.

SIL.

Fengchu Shale. Yellowish-green, greenish-grey, grey and black shales of undetermined thickness are believed to be equivalent to the Fengchu Shale found in other parts of Chekiang, and are therefore assigned to the Silurian.

ORDOVICIAN

Yenwashan Series. Greenish-grey, green and black shales interbedded with impure limestones. Total thickness over 300 m.

Yinchu Series. Upper part, impure limestones with siliceous beds in the uppermost part; middle part, shales and sandstone, yellow, green, or grey in colour, sometimes calcareous in composition, about 500 m. thick, yielding *Didymograptus indentus* HALL, *D. nicholsoni* LAPW., *Dichograptus octobrachiatus* HALL, and *Lingula modesta* ULRICH in a yellow phyllitic shale; lower part impure limestones sometimes intercalated with bands of argillaceous material, and replaced by a black slaty shale at the base. This black shale usually exhibits an oily lustre, and sometimes changes laterally into a coal-seam of inferior quality. Thickness, including impure limestones, 400 m.

(37) EASTERN CHEKIANG

TERT.

Basalt. Rich in olivine and magnetite; about 30 m. thick.

Chukiang Sandstone. Purplish-red, friable sandstone with occasional conglomerate and yellowish-green sandstone in which occur plant remains. Thickness 400 m.

CRETACEOUS

Rhyolite, quartz porphyry and rhyolite tuff invaded by granite. Thickness 500-600 m.

Shaohsin Tuff. Light green tuffaceous agglomerate interbedded with trachytic flows. Thickness 600-800 m.

Hutoushan Conglomerate. Purple conglomerate interbedded with tuff, agglomerate, thin beds of rhyolite and occasional layers of andesite. Thickness 380 m.

Juao Volcanic Series. Trachy-andesite, trachyte, andesitic and trachytic tuff with thin beds of rhyolite. Thickness 170 m.

PERM.

Feilaifeng Limestone. Thin-bedded cherty limestone with a bituminous shale at the bottom. Thickness 150 m.

L. Carb.

Chienlikang Sandstone. Quartzitic conglomerate in the upper part, and green and purple sandstone with some shales in the lower part. Thickness 600-800 m.

Sil.

Fengchu Shale. Yellow and green shales, about 200 m. thick.

L. Ordovician

Yinchu Series. Yellow shale intercalated with thin layers of fine sandstone yielding *Phyllograptus anna* Hall, *Tetragraptus bigsbyi* Hall and *Didymograptus nitidus* Hall, passing downward into alternating beds of yellow shale and thin, argillaceous limestone, followed still lower down by thick-bedded siliceous limestone and quartzitic sandstone. Total thickness about 380 m.

Wutai?

Chuchih Metamorphic Series. Quartzite and marble followed downward by quartz-mica-schist, hornblende-schist and gneiss.

(38) South-Western Chekiang

Chukiang Red Beds. Soft red sandstones with a thick basal conglomerate believed to be of Tertiary age.

Cretaceous

Rhyolite Flows. Bedded rhyolite with large phenocrysts of felspar and quartz and some glassy groundmass. Thickness about 700 m.

Kienteh Series. Purple sandstones, purple shales, variegated tuff-sandstone, tuff-conglomerate, tuff, volcanic ash, conglomerate, green sandstone and shale intercalated with beds of rhyolite. *Estheria elliptica* Dunker var. *intermedia* Chi occurs in the middle part. Thickness 700-1,000 m.

Permian

Lishien Series. Largely yellow and brown sandstones in the upper part, and black shale with poor coal-seams in the lower part.

Feilaifeng Limestone. Massive cherty limestone with *Orthotichia morganiana* (Derby), *Streptorhynchus* (*Kiangsuella*) cf. *pectiniformis* Dav. and fusulinids. Thickness 200 m.

Chienlikang Sandstone. Upper part, mainly white quartzite and quartzitic conglomerate, about 200 m. thick; lower part, massive, close-grained green sandstone, about 500 m. thick. At least the upper part of this formation belongs to the Lower Carboniferous; the lower part possibly belongs to the Devonian or Silurian.

? Sil.

Fengchu Shale. Green and yellowish-green shales with *Monograptus* and *Climacograptus* in the basal part. Thickness about 300 m.

Ordovician

Yenwashan Series. Alternating beds of green calcareous shales and shales with lenses of limestone, occasionally containing thin-bedded impure limestone. *Orthoceras sinensis* occurs at the top, and graptolites, such as *Dicellograptus, Climacograptus* and *Glossograptus hincksi* (Hopk.) in the lower horizons. Thickness 400-500 m.

ORDOVICIAN

Yinchu Series. Upper part, mainly consisting of impure limestones alternating with earthy bands, about 300 m. thick; middle part, sandstones and shales, black, yellow and greenish-grey in colour, becoming calcareous in the higher horizons, 300-400 m. thick; lower part, chiefly earthy limestones with a series of carbonaceous black shale forming the base. So carbonaceous is the material that it can be used for lime-burning. The middle part has yielded *Didymograptus hirundo* SALTER and *D. erratulus* HALL. In a black shale which probably belongs to the lower part *Didymograptus nicholsoni* LAPW., *D. simulans* LAPW., *Phyllograptus* cf. *angustifolius* HALL, *Glyptograptus* and *Dicranograptus* have been found.

Taoshuiwu Series. Close-grained, dark sandstones and conglomerate questionably assigned to the Cambrian.

(39) NORTHERN FUKIEN

CRETACEOUS

Wuyi Series. Largely consisting of igneous material, divisible into three parts: upper part, rhyolite with quartz-porphyry; middle part, a series of conglomerates, red sandstones, shales, tuffs and tuffaceous conglomerates, forming the precipitous range of the Wuyishan; lower part, quartz porphyry, tuff, and black and grey shales with crustacea. Total thickness 1,700 m.; probably partly equivalent to the Nancheng Series of central Kiangsi.

JURASSIC

Lihshan or **Tsungjen Series.** White and greenish-grey sandstones sometimes altered to quartzite with coal-bearing shales and conglomerates. Coal-seams are locally altered to graphite. *Clathropteris meniscoides* BRONGN., *Podozamites lanceolatus* LIND. and HUTT., and *Pityophyllum longifolium* MOLL. often occur. Thickness over 1,000 m.

Lipichiao Series. Grey and black shales interstratified with well-bedded grey sandstone containing thin seams of coal and the same plant remains as in the overlying series. Thickness about 400 m.

PERMIAN

Chunglingchiao Limestone. Grey to black, pure limestone with corals and fusulinids and lenticular bodies of flint, often used for lime-burning, typically exposed in the Nanping district. Thickness 70-100 m.

CARBON.

Chinhsien Series. Quartzitic sandstone with silvery grey shales and sandstones in the middle part in which occur variable layers of coal, typically developed near Nanping.

WUTAI or SINIAN

Linchuan Series. Mica- and chlorite-schists, phyllites, quartzites with irregular layers of white marble, often penetrated by porphyries and numerous quartz veins which are sometimes cupriferous.

ARCH.

Shakuan Complex. Chiefly gneissic rocks with numerous igneous intrusions in which granite predominates, quartz veins numerous, often auriferous.

(40) SOUTHERN FUKIEN

TERTIARY

Nantaiwu Beds. Loose conglomerate, sandy gravel, white sand, fireclay and black shale with a seam of lignite, developed near Amoy.

Lungchih Red Beds. Red clay often crowded with oysters, and sometimes alternating with gravels, loose conglomerate and greyish fireclay in which occur fragments of plants.

Haicheng Volcanic Series. Tuffaceous sandstones in the upper part, basalt flows in the middle, and volcanic agglomerate in the lower part. Thickness over 200 m.

CRETACEOUS

Touling Formation. Largely rhyolite with subordinate tuff and andesite, usually associated with quartz-porphyry and sometimes interbedded with red sandstone.

Paisha Series. Mainly red sandstone with variegated clay-shale and conglomerate containing here and there thin layers of coal. Thickness about 300 m.

TRIASSIC

Yangping Shale. Red, yellow and green shales intercalated with thin sandstones. In the shales occur marine pelecypods probably belonging to *Anoplophora* and plant remains such as *Pterophyllum*, *Ctenis*, etc. Thickness about 170 m.

UPPER PERMIAN

Hukou or **Tsuipingshan Shale.** Green, grey and yellowish-brown shales, gradually replaced in the upper part by thin-bedded quartzose sandstone. Marine and fresh-water organisms as well as plants occur in the shales. *Gastrioceras* sp., *Anthracomya* cf. *lævis* DAWSON, *A. wardiformis* GR., *Carbonicola turgida* BROWN, *C. wangsoweni* GR., *C.* aff. *subrotunda* BROWN, *Estheria fukienensis* (? = *E. portlocki* JONES), *Productus cora* var. *fukienensis* CHAO, *Productus gratiosus* WAAGEN, *Schizodus*, *Orthotetes ?*, *Solenomorpha ?*, scales of ganoid fish, and ammonoids occur among the fauna, and *Lobatannularia lingulacus* HALLE and *Neocalamites* among the flora. Thickness about 250 m.

M. PERM.

Gigantopteris Formation. Shales and sandstones with a seam of anthracite; sandstone abounds in the upper part and shale in the lower part. *Gigantopteris nicotianæfolia* SCHENK and *Sphenophyllum thoni* MAHR occur frequently. Thickness 250 m.

L. PERM.

Chihsia Limestone. Grey and black limestones with numerous flints which are sometimes arranged along the bedding planes. Fusulinids abound. Thickness a few metres to 300 m.

L. CARBON.

Nanching Quartzite. Divisible into three parts: upper part, grey and black sandy shales intercalated with quartzose sandstone and conglomerate, about 200 m. thick; middle part, an alternating series of shale, quartzite, slate and claystone, about 200 m. thick; lower part, massive quartzite intercalated with a few layers of shale, about 300 m. thick. Total thickness over 700 m.

ARCHÆAN

Banded, granitoid gneiss often associated with intrusive granite, quartz-porphyry, quartz veins and basic igneous rocks, well-exposed along the coast.

(41) EASTERN KUANGTUNG

Recent deposits. Yellowish sandy clay less than 6 m. thick on the average.

Well-consolidated coarse conglomerate, only developed along the present valleys, about 1 m. thick.

TERTIARY?

Red Beds. Mainly conglomerates or conglomeratic sandstones of dark red or purplish colour; purple shales are locally developed in the uppermost part of the series. Basalt and rhyolite are present among the pebbles in the conglomerate. Thickness 180-200 m.

MESOZOIC

Volcanic Series. Rhyolite, quartz porphyry, granophyre, etc. A part of this igneous series is probably intrusive.

Chinshuwo Series. Brown sandstones and coal-bearing shales with *Ptilophyllum acutifolium* MORRIS and *P.* (*Anomozamites*) *inconstans* BRAUN. The sandstone is sometimes greenish in colour and sometimes highly ferruginous.

Shenchuan Series. Slates or metamorphosed shales interbedded with schistose quartzites, partly whitish-grey or pale red in colour, and partly variegated. Thickness 700-800 m.

PERMIAN

Huangkang Series. A complex series of brown, green, and reddish sandstones and purple or grey shales, usually containing a thick stratum of massive white quartzite. The sandstones are sometimes thick-bedded and sometimes thinly stratified, and the shales are occasionally bituminous. Total thickness about 3,700 m.

L. CARBON.

Yinteh Limestone. Dark-grey to bluish-grey, thick-bedded limestone becoming argillaceous towards the top. The uppermost argillaceous beds often contain nodules of limestone associated with fossiliferous layers. Thickness about 230 m.

DEVONIAN

Mangtsuhsia Series. Upper part, shales with interbedded sandstones becoming more sandy in lower horizons, about 500 m. thick; middle part, mainly shales, containing siliceous concretions, intercalated with some shaly sandstones, brownish, yellowish or pale-red in colour, about 100 m. thick; lower part, quartzose and micaceous sandstones and conglomerates which latter are usually thick-bedded, greyish-white at the base, about 1,000 m. thick.

Metamorphic Group. Gneisses, schists, phyllites and slates frequently penetrated by granite, quartz veins, and occasionally by gabbro.

(42) Hong Kong and its Neighbourhood

Recent Deposits.

Starling Formation. "Block-agglomerate" or "calcite-bearing conglomerate" composed of large and small fragments of red quartz-porphyry, red sandstone and shale and large blocks of limestone. These pyroclastics are apparently underlain by black, marly shale which contains a metamorphosed limestone. The latter is in turn underlain by green tuffaceous rocks. The bulk of the lower part of the series is formed by massive quartz-porphyry. Well exposed on the south-eastern side of the Starling Inlet and in Kato Island (?=Repulse Bay Formation).

Red Beds. Red sandstones with intercalated clay-shales in the upper part and variegated conglomerate in the lower part. Pebbles in the conglomerate chiefly consist of sub-rounded fragments of quartzite and quartz-porphyry derived from the underlying formation. Probably Cretaceous.

JURASSIC

Tolo Crest Formation. White or greenish quartzites and cross-bedded quartzose red sandstones intercalated with shales. A thick quartzose conglomerate forms the lower part. Visible thickness about 250 m.

Tolo Channel Formation. Quartzose conglomerate, clay-shales and quartzitic breccia with some black shale in which occur *Hongkongites hongkongensis* (Gr.) and *H. angulatoides* (Quenstedt), a genus related to *Schlotheimia*.

Shamchun Series. Upper part, white phyllitic quartzite, quartzitic slate, argillaceous sandstone, slate and clay-shale; middle part, grey to reddish phyllites; lower part, grey quartzose sandstone, highly compact and semi-crystalline in texture. Total thickness probably over 2,000 m.

(43) Northern Kuangtung

Red Beds. Upper part: blood-red shales and clays intercalated with some red sandstones, well-developed in the Nanhsiung district where its thickness varies from 300 to 400 m. Lower part: red conglomerate intercalated with false-bedded red sandstones, about 300 m. thick, well-developed in the Tanhsiashan, south of the Jenhua district.

PERMIAN

Huangkang Series. Interbedded sandstones and shales of reddish, yellowish-brown or dark grey colours with sandstones predominating in the upper part and shales in the lower. Thin coal-seams and limestone sometimes occur near the base. Thickness about 200 m. as exposed in the Huangkangling, north of Shaokuan, and in the vicinity of Shihsing city, but increasing to about 300 m. in the southern part of Kuangtung, *e.g.*, in the Peiyunshan, north of Canton.

Shaokuan Limestone. Limestones interstratified with dark shales and shaly sandstones in the upper part passing downward into a massive dark grey limestone. The shaly limestone in the upper part contains *Spirifer regulatus* Kutorga, *Rhipidomella pecosi* (Marcou)?, *Pugnax* cf. *uta* (Marcou), *Streptorhynchus* cf. *semiplanus* Waagen, *Orthotetes ruber* Frech, *Productus* (*Striatifera*) *compressa* Waagen, *P.* (*S.*) *auroculata* Yoh, *P. gratiosus* Waagen, *P. semireticulatus* var.?, *Camarophoria* sp., *Chonetes* sp., *Tetrapora elegantula* Yabe and Hayas., *Favosites* sp., and *Syringopora* sp. Numerous fusulinids occur in the massive limestone. Total thickness about 150 m.

L. CARBON.

Yinteh Limestone. Massive limestone with siliceous concretions, passing into calcareous shales interbedded with shaly limestones in the basal part. Fossils in the massive limestone: *Euomphalus subcircularis* Mansuy, *Orthoceras* cf. *epigrus* Hall, *Actinoceras* sp., *Fenestella* cf. *cestriensis* Ulrich, *Zaphrentis* (*Hapsiphyllum*) *calcariforme* Hall, *Syringopora* sp. Thickness 220-230 m.

Mangtsuhsia or **Meiling Series.** Variegated massive sandstone, locally quartzitic, becoming coarser in the lower part, and finer towards the top. In the uppermost part micaceous shales are often intercalated with the fine-grained sandstone. Thickness exceeding 1,000 m. Probably Devonian.

Granite. Mainly intrusive.

(44) Western Kuangtung

Red Loam. Red and yellowish-red sands and clays with basal gravel.

TERTIARY

Tatai Formation. Ferruginous sandstone interstratified with beds of limonite which contain Tertiary plants. A thick conglomerate or breccia cemented by ferruginous sands and clays forms the basal part. Typically developed at Tataiyung and Shanshuiwei in the vicinity of the city of Yunfu.

TERT.

Red Beds. Shales, soft sandstones and conglomerates of dark red colour, widespread in the Kaoyao, Yunfu and Yunan districts.

CRETACEOUS

Huapiaoshih Series. Alternating beds of purple sandstone and shale intercalated with tuffs and thin sheets of contemporaneous lava in the upper part, followed downward by massive agglomerates and conglomerates; a dark red felsite lies at the base. Thickness about 400 m.

JURASSIC ?

Hsiaoping Series. Brownish sandstone, whitish yellow quartzite and coal-bearing shales which yield plant remains attributable to *Cladophlebis* cf. *haiburnensis* (L. and H.), *Clathropteris meniscoides* BRONGN., *Nilssonia rajmahalensis* MORRIS, *Ptilophyllum acutifolium* MORRIS, *P. inconstans* BRAUN., and *Podozamites* sp.

Tsihsingyen Limestone. Massive, light-grey limestones containing scattered fragments of corals and crinoidal stems. Thickness about 200 m.

L. CARBONIFEROUS

Shikang Formation. Shales, sandstones and white quartzite in the upper part, limestones in the lower, which are partly thin-bedded, black and impure, and partly massive and whitish or bluish-grey. Fossils found in the uppermost part of this series, including *Schellwienella* cf. *crenistria* (PHILL.), *Chonetes hardrensis* var. *kansuensis* CHAO, *Productus undatus* (DEFR.), *P. semireticulatus* MARTIN?, *Cystophrentis* aff. *kolaohoensis* YU, *Pseudouralinia* sp., *Syringopora* sp., and *Diphyphyllum* cf. *platiforme* YU.

Tinghushan Series. Chiefly sandstones and shales with occasional intercalations of quartzites, slates and conglomerates near the base. Thickness about 1,000 m.

SILURIAN

Leintan Shale. Grey to black shales with intercalated yellowish sandstone in the upper part, yellowish sandstone alternating with variegated shales in the lower part. Fossils in the black shale at the top: *Retiolites geinitzianus* BARR. var. *spinosus* CHANG, *Diplograptus* (*Orthograptus*) sp., *Monograptus spiralis* GEIN., *M. exiguus* NICH., *M. halli* BARR., *M. gregarius* LAPW. Typically exposed in the Yunan district.

Lunghuyen Limestone. Black shales and thin-bedded argillaceous limestone with shaly partings in the top part, passing downward into whitish dolomite and then massive blue limestone with crinoidal stems. Believed to be Ordovician.

SINIAN?

Lungshan Series. Grey and yellowish, schistose sandstones intercalated with greenish-grey phyllites, white quartzites, black slates and variegated shales and sandstones. Total thickness probably exceeds 1,000 m.

[The term Lungshan Series is here used in a restricted sense.]

Wutai Formation? Schists with some quartzites, marbles and slates exposed in the southern part of the Kaoyao and Yunfu and the north-eastern part of the Kaoyao and Fungchuan districts.

Archæan. Gneisses with large crystals of felspar and marked foliation due to the presence of parallel layers of mica; extensively exposed in the Kaoyao, Yunfu, Kaomin and Hsinsin districts.

(45) MIDDLE PART OF THE EASTERN NANLING

Reddish yellow loam and clay with gravels.

Kengyang Sandstone. Red sandstone with conglomerate near the base. Probably early Tertiary.

JURASSIC

Kenkou Series. Sandstones and coal-seams in the upper part, quartzose sandstone, coal-bearing shales and sandstones with *Tænio-pteris macclellandi* OLD. and MORR.?, *Podozamites lanceolatus* (L. and H.), *Ptilophyllum acutifolium* MORR., *Pterophyllum nathorsti* SCHENK, *Nilssonia* cf. *princeps* OLD. and MORR. in the middle part, and sandstones and conglomerates at the base. Thickness 170 m.

Chinglung Limestone. Thin-bedded limestone alternating with shales. Thickness 30 m. Age: Triassic, or partly Permian.

PERMIAN

Deoling Series. Black shales, sandstones and siliceous beds with one stratum of limestone in the middle part and one near the top. *Palæofusulina? meitienensis* CHEN occurs in the upper limestone, and *Gigantopteris* in the coal-bearing shales. Thickness 270 m.

Chingchichung Limestone. White, lumpy limestone. Thickness variable and uncertain, but not great.

Kuhfeng Beds. Black, cherty shale with *Gastrioceras*.

Chihsia Limestone. Black limestone containing flint concretions. *Tetrapora* and *Michelinia* frequently occur. Total thickness from the top of the Chingchichung Limestone to the bottom of the Chihsia amounts to 120 m.

URALIAN

Maping Limestone. Light grey pure limestone, more or less silicified at intervals, swarming with *Schwagerina princeps* EHRENB. Thickness 400 m. Age: Uralian.

Huanglung Limestone. White, lumpy limestone occasionally silicified. Thickness 100 m. Age: Middle Carboniferous.

L. CARBON.

Linwu Series. Black limestone, full of nodules of flint, containing *Gigantella, Kueichouphyllum sinensis* YU, *Yuanophyllum, Lithostrotion irregulare* PHILL., *Corwenia minor* YU, *Dibunophyllum, Kwangsiphyllum* and *Lonsdaleia floriformis* (MARTIN), with a series of sandstones and coal-bearing shales in the upper and middle parts.

L. CARBON.

Shitzuchu Series. Black limestone rich in flint-concretions, interbedded with black shale at intervals, thin-bedded in the upper part, becoming thick-bedded and almost free of flints in the basal part. *Gigantella, Syringopora, Pseudouralinia tangpakouensis* YU and *P. irregularis* YU abound in the higher horizons, and *Camarotœchia, Eochoristites* and *Cystophrentis* in the lower. Total thickness of this and the overlying series reaches 820 m.

DEVONIAN

Kuhua Limestone. Dark limestone alternately thick and thin-bedded, becoming impure and shaly towards the top, massive and crystalline towards the basal part. Bryozoa abound in the lower part. Thickness 580 m.

Liukiang Series. Thin-bedded limestone interbedded with shales. *Stringocephalus* and *Atrypa desquamata* Sow. are among the leading fossils.

Lienhua Sandstone. Yellow sandstone and shales with lamellibranchs and plant remains in the upper part; purple and buff sandstones in the lower part, and conglomerate at the base. Total thickness of this and the overlying series is estimated at 340 m.

Pienchi Series. Dark grey slates, base not exposed.

(46) MENGCHULING (CENTRAL NANLING)

Red Clay or **Loam.**

Red Conglomerate and **Breccia** with a marly matrix.

L. CARBONIFEROUS

Sihwan Series. Sandstones and coal-bearing shales containing *Lepidodendron* and brachiopods.

Lower Carboniferous Limestone. A series of dark blue to black limestones containing bands or nodules of flint at intervals, sometimes thin-bedded and sometimes thick-bedded, becoming shaly and carbonaceous towards the top. The basal part is also composed of shales and shaly limestone. *Pseudouralinia* occurs in the lower part and *Kueichouphyllum* and *Gigantella* in the upper part. Total thickness about 600 m.

DEVONIAN

Kuhua Limestone. Light and dark grey to dark blue limestone, globulitic in the upper part, and black and carbonaceous in the lower part. The thick-bedded horizons are usually full of bryozoa. A greenish or purplish shale occurs at the top, and greenish-grey or yellow, fissile shale at the bottom. Thickness 440 m.

Huangniu Sandstone. Mainly thick-bedded sandstone, brown and purplish in colour, occasionally intercalated with purple, yellow and

DEVONIAN

green shales. In certain facies a bed of argillaceous limestone with brachiopods is included in the middle part, and a yellow shale with plant remains and pelecypods in the lower part. Thickness 700-1,000 m.

SIL. OR ORD. ?

Shuikou Series. Slates, shales, sandstones and mudstones, often grey or purple in colour, but sometimes white, and generally hardened to a notable extent. The shales in the lower part are more or less schistose, frequently traversed by quartz veins. Thickness well over 1,000 m. Probably representing Silurian or Ordovician or both.

Matoupu Series. Fissile shales, reddish-brown or buff in colour, divided into thick strata occasionally intercalated with brown sandstone, and invaded by granite with which are associated ramifying hæmatite veins. Thickness at least 1,000 m. Believed to be of Sinian age.

Fuhyungshan Gneiss. Mica-garnet-schist, hornblende-gneiss, and granitoid gneiss with gneissic banding usually well-developed. Auriferous quartz veins sometimes cut across the gneisses. Other metalliferous deposits also occur.

(47) Tupangling (Central Nanling)

Red Clay with basal gravel.

Purplish Red Sandstone, often conglomeratic, particularly in the lower part. Thickness 500 m. Probably early Tertiary.

L. CARBONIFEROUS

Linwu Series. Grey limestone interstratified with shales and thin sandstones in the upper part becoming massive and thick-bedded in the lower part. Nodules of flint occur in the higher beds, but free from flints in the lower. *Gigantella giganteus* (MART.) and *Kueichouphyllum* are found in the higher horizons, and *Syringopora* and *Pseudouralinia* in the lower. Thickness about 350 m.

Ssumen Series. Shaly limestone and shales with *Eochoristites*. Thickness 80 m.

Shitzuchu Limestone. Thick-bedded grey limestone with *Cystophrentis*. Thickness about 200 m.

DEVONIAN

Shoufuhssu Series. An alternation of sandstones, shales and shaly limestones in the upper part; thick-bedded grey limestone with *Sinospirifer* in the middle part; and a relatively thin series of sandstones and shales in the lower part. Thickness 260 m.

Chiaotou Limestone. Thick- and thin-bedded grey limestone, rich in bryozoa, crystalline in the lower part. Thickness about 740 m.

DEVONIAN

Stringocephalus Beds. Thin-bedded limestones and shales with *Stringocephalus*.

Lienhua Sandstone. Purple and yellow sandstones with plant remains, occasionally interstratified with conglomerate. Basal conglomerate is usually present.

Pienchi Series. Dark slates, shales and sandstones of undetermined thickness.

(48) NORTHERN KUANGSI AND MID-WESTERN NANLING

Reddish-yellow and yellowish grey clay containing fine sand and layers of gravel in the lower part.

Pakseh Series. Greenish-grey sandstones and shales, the latter being sometimes calcareous and fossiliferous; only developed in the Tunglan, Fongshan, Lingyun and Pakseh districts. Probably Triassic. Thickness about 600 m.

PERMIAN

Tunglo Series. Yellowish-grey sandstone and black shale. Thickness over 500 m.

Maokou Limestone. Thickness 100 m., only developed in the Lingyun district, north-western Kuangsi.

Chihsia Limestone. Thin-bedded, black limestone containing flints at intervals, and now and then interstratified with shales. The limestone yields *Pseudofusulina gregaria* LEE indicating a lower horizon of the Chihsia Limestone proper. *Tetrapora* also occurs. Thickness about 100 m.

URALIAN

Maping Limestone. Light grey and pinkish limestones of extraordinary purity containing *Triticites parvulus* (SCHELLW.), *Quasifusulina longissima* (MÖLLER), *Schwagerina fusulinoides* SCHELLW., and *Schwagerina princeps* EHRENB. Thickness 170 m.

M. CARB.

Huanglung Limestone. Light grey to white limestone, partly silicified in the upper part, often brecciated and re-cemented by lime in the lower part, containing *Fusulinella bocki* MÖLLER and *Chætetes quadrangulatus* YU. Thickness 240 m.

L. CARBONIFEROUS

Locheng Limestone. Dark grey and brown, impure limestones, becoming thin-bedded in the lower part with shaly partings and nodules or bands of flint. The middle and lower parts yield *Caninia* sp., *Syringopora* sp. and *Lithostrotion* (*Siphonodendron*) *curvatum* YU and the peculiar shell *Lochengia* (*Eochoristites?*). Thickness 35 m.

Ssumen Series. Carbonaceous shale with coal-seams and thin layers of limestone. The coal-bearing shale is usually rich in iron pyrites. Ill-preserved brachiopods and corals abound, including *Cor-*

L. Carboniferous

wenia minor Yu and *Syringophyllum permicum* Gr. and Yoh. Thickness about 40 m.

Shitzuchu Series. Upper part, black shale and limestone with bands of flint, containing *Caninia, Syringopora, Prismatophyllum, Pseudouralinia* and abundant foraminifera; middle part, yellow sandstones and shale, sometimes ferruginous, usually carbonaceous or calcareous in the upper layers; lower part, thin-bedded black limestone with *Cystophrentis kolaohoensis* Yu and *Pseudouralinia*. Total thickness 160 m.

U. Devon.

Yunghsien Limestone. Pure, white limestone frequently used for lime-burning, containing *Yunnanella*.

Kuhua Limestone. 600 m.

Pauhsien Shale. Black shale with *Sinospirifer chaoi* Gr. In certain facies this shale is replaced by black shaly limestone with *Sinospirifer vilis* Gr.

Middle Devonian

Mingyu Limestone. Shaly limestone with *Stringocephalus burtini* Defr., *Reticularia maureri* Holza., *Atrypa desquamata* var. *kansuensis* Gr., *A. aspera* var. *kwangsiensis* Gr., *Meristella tumidioides* Gr., and *M. athyriformis* Gr.

Hualyuan Beds. These beds are exposed near Huaiyuan, Ishanhsien, containing *Camarophoria huatiformis* Gr., *C. latiplicata* Gr., and *Stringocephalus burtini* mut.

Kangma Beds. Exposed in the Hochih district yielding *Atrypa desquamata* Sow., *A. reticularis* Linn., *Spirifer* cf. *officialis* Kayser, *Reticularia maureri* Holza., *R. pachyrhynchoides* Gr., *Spiriferina octoplicatoides* Gr., *Cyrtiopsis?*, and *Columnicrinus pentalotuba* Gr.

Liukiang Group. 50-400 m.

Liangshulao Beds. These beds consist of black shaly limestone and carbonaceous shale containing *Productella productoides* var. *sinensis* Gr., *Schizophoria striatula* Schloth., *Camarophoria bitingi* Gr., *C. tritingi* Gr., *C. quadritingi* Gr., *C. pentatingi* Gr., *Hypothyridina procuboides* var. *hochihensis* Gr., *H. parallelepipeda* Kays., *Atrypa desquamata* var. *kansuensis* Gr., *Reticularia pachyrhynchoides* Gr., *R. maureri* Holza., *R. lensiformis* Gr., *Meristella playellii* Mans., *Stringocephalus burtini* mut., *S. obesus* Gr., *S. obesus* var. *grandis* Gr., and *Bactrites indifferens* Gr. As exposed in the Hochih district they reach 200 m.; elsewhere only 50 m. thick.

Tungtang Formation. Exposed in the Lingchuan district, containing *Productella* cf. *subaculeata* de Koninck, *Schizophoria macfarlanii* var. *kansuensis* Gr., *Atrypa desquamata* (several var., including var. *auriculata*), *Atrypa aspera* var. *kuangsiensis* Gr., and *Reticularia lensiformis* Gr. Bryozoa abound.

Tangkou Sandstone. More than 300 m. thick, probably equivalent to the Lienhua Series.

L. DEVON.?

Lienhua Series. Plant-bearing black shale with thin layers of fine sandstone and sandy shales in the upper part, thick-bedded orange and purple sandstones with shaly partings in the lower part. Basal conglomerate often present. Thickness tends to increase towards the north-east, varying from 20 m. to 160 m. Probably Lower Devonian.

Chingchih Series. Upper part, greenish-grey, fine sandstone, sandy shale, black shaly slate and phyllitic shales, about 500 m. thick; middle part, grey and black phyllitic shales and impure limestones occasionally intercalated with greenish-grey fine sandstone, about 500 m. thick; lower part, mainly black slaty shale intercalated with carbonaceous shale and laminated shaly limestone. The lowest part is often composed of a siliceous shale, about 300 m. thick. Age undetermined.

Nanling Series. Greenish-grey sandstone with occasional conglomerate near the top passing downward into greenish-grey shale interstratified with fine sandstone, often rendered schistose. Quartz veins are abundant. Thickness well over 1,000 m. Age uncertain.

(49) CENTRAL AND EASTERN HUNAN

Reddish and **yellowish clay** with pockets of gravel.

Dark red or **dark brown clay** often mottled; sometimes containing sands and sometimes pure, showing vertical joints and forming miniature cliffs.

Paishatsing Gravel. A gravel of medium grade consisting of well-rounded and even-sized pebbles of quartz and yellowish clayey material. Thickness 2-5 m.

TERTIARY

Tanshih Red Beds. Upper part, an alternation of thin-bedded reddish sandstone and shale with occasional layers of bluish-grey or greenish-yellow shale; middle part, massive, coarse, red sandstone with scattered pebbles of all sizes; lower part, red soft conglomerate with pebbles derived from Palæozoic limestones, Nanyoh Granite and the Hengyang Red Sandstone. Total thickness 300-400 m.

CRETACEOUS?

Hengyang Red Sandstone. Red sandstone and shale with beds of gypsum and rock salt and occasionally fish remains, succeeded downwards by a thick-bedded, close-grained, reddish sandstone extensively used for building purposes, then by a basal conglomerate composed of large and small pebbles and angular boulders or fragments of Palæozoic limestone, quartzitic sandstone and a phyllitic shale. These are tightly cemented by a reddish sandy material. Thickness over 700 m.

TRIAS.

Thin-bedded Limestone. Bluish-grey, thin-bedded limestone passing downward into a yellow shale intercalated with thin bands of limestone. Thickness more than 200 m.

U. PERMIAN

Luipakou Beds. Chiefly siliceous and sandy shales containing *Pseudomonotis radialis* WAAGEN, *Aviculopecten coxanus* SHUM. var. *sinensis* FRECH, *Leda præacuta* WAAGEN, *Nucula beyrichi* SCHAU., *Pleurophorus subovalis* WAAG., *P.* cf. *acuteplicatus* WAAG., *Schizodus pinguis* WAAG., *S. compressus* WAAG., *Astarte ambiensis* WAAG., *Allorisma* cf. *subelegans* MEEK, *Edmondia* cf. *nebrascensis* GEIN., *E. tiesseni* FRECH and *Bellerophon* sp.

Deoling Series. Sandstones and carbonaceous shales with nodules of pyrites and several workable coal-seams. *Gigantopteris nicotianæfolia* SCHENK, *Annularia maxima* SCHENK, *Cyclopteris trichomanoides* BRONGN., *Neuropteris* cf. *flexuosa* STERNB., *N. angustifolia* BRONGN., *Pecopteris* cf. *unitus* BRONGN., *P.* cf. *miltoni* GOEPPERT, and *Cordaites principalis* GERMAR abundantly occur in the coal-bearing beds. Thickness over 100 m.

Gastrioceras Beds. Siliceous shale, chert and carbonaceous limestone with *Gastrioceras zitteli* GEMM. Thickness up to 50 m.

L. PERMIAN

Chingchichung Limestone. Whitish-grey, massive, semi-crystalline limestone crowded with *Doliolina lepida* (SCHWAGER). Thickness 80-120 m.

Shuitung Limestone. Dark-grey, thin-bedded limestone with bands of chert in the upper part, and carbonaceous shales and whitish-grey limestone in the lower part containing two series of siliceous beds: one at the top and the other in the lower part. Fossils are: *Lyttonia, Michelinia siyangensis* REED, *M. disjuncta* HUANG, *M. indica* WAAGEN and WENTZEL, *Caninia liangshanensis* HUANG, *Geinitzella* cf. *crassa* LONSDALE, *Orthotetes tingi* GR., *Orthotichia morganiana* (DERBY), *Michelinia multicystosa* YOH, *Productus* cf. *yangtzeensis* CHAO. Thickness 280-350 m.

Hutien Limestone. Upper part, light to dark grey limestone, sometimes globulitic, containing *Schwagerina princeps* (EHRENBERG), *S. fusulinoides* SCHELL. and *Triticites contractus* (SCHELL.); lower part, dense, massive, white or greyish-white limestone with numerous flesh-coloured streaks. Thickness 80-150 m. The upper part of this limestone undoubtedly belongs to the Uralian, but the lower part with *Chætetes raritabularis* LEE and CHU and *Caninia simpliseptata* CHI probably belongs to the Moscovian.

L. CARBONIFEROUS

Tzemenchiao Limestone. Flinty limestone in the upper part, and an alternation of limestones and shales in the lower part. Fossils: *Productus* (*Gigantella*) *edelburgensis* (PHILL.), *P.* (*Gigantella*) *giganteus* MARTIN, *P. inflatiformis* GR. and TIEN, *P. semireticulatus* MARTIN, *P. graciosus* var. *occidentalis* SCHELLW., *P.* (*Hunanella*) *antiquatiformis* GR. and TIEN, *P. sinuata* GR. and TIEN, *Spirifer liangchowensis* CHAO, *Spiriferina octoplicata* SOW., *Rhipidomella michelini* var. *minor* GR., *Schizophoria presupinata* GR. and TIEN, *Dielasma ficum*

Gr. and Tien, *Schellwienella crenistria* Phillips, *Yuanophyllum kansuense* Yu, *Heterocaninia tholusitabulata* Yabe and Hayasaka, *H. paochingensis* Yu, *Auloclisia multiplexeum* Yu, *A. densinum* Yu, *Diphyphyllum (Depasophyllum) hochangpingensis* Yu, *Lithostrotion portlocki* var. *depasophylloidea* Yu, *Siphonodendron hunanense* Chu, *Syringopora* sp.

Tseishui Series. Quartzitic sandstone intercalated with coal-bearing shales in the middle part. Thickness 30-100 m.

LOWER CARBONIFEROUS

Shihtengtze Limestone. Upper part, alternating beds of bluish-grey, shaly limestone and greyish shale; middle part, slabby dark limestone with shaly partings; lower part, dark blue limestone with shaly partings merging downward into sandstones and shales. Fossils: *Gigantella* cf. *edelburgensis* (Phill.), *G. giganteus* (Martin), *Productus inflatiformis* Gr., *Linoproductus groberi* (Krenkel), *L. tenuistriatus* (Verneuil), *Spiriferina octoplicata* Sow., *Siphonodendron* cf. *pentalaxisoidea* Yu, *Thysanophyllum circulocysticum* Chu, *Syringopora*. The whole series amounts to 110-150 m. in the southern part of the area, but is reduced to 60-70 m. in the district of Changsha, and is there replaced by shales.

Mengkungao Series. Upper part, dark grey limestone breaking into thin slabs capped by a bed of limestone full of hæmatite nodules; about 160 m. thick. Middle part, dark grey or bluish-grey limestone, sometimes shaly, about 60 m. thick, containing *Composita globularis* (Phill.), *Camarotœchia kinlingensis* Gr., *Spirifer* sp. and *Syringopora* sp. Lower part, thin shales and sandstones with calcareous bands, 50-80 m. thick, richly fossiliferous. The common forms are: *Neoproductella kolaohoensis* Gr. and Tien, *N. hunanense* Gr. and Tien, *N. tenuistriata* Gr. and Tien, *Productus oblongus* Gr. and Tien, *Camarotœchia hunanense* Gr. and Tien, *C. kinlingensis* Gr., *Schellwienella crenistria* mut., *Schuchertella lianglukowensis* Gr. and Tien, *Spirifer fissiplicata* Gr. and Tien, *S. (Brachythyris) disconcenstus* Gr. and Tien, *Martiniella nasuta* Gr. and Tien, *Ambocœlia tanpakowensis* Gr. and Tien, *Composita asgintia* Gr. and Tien, *C. globularis* (Phill.), *C. subplicata* Gr. and Tien, *Cystophrentis kolaohoensis* Yu, *Syringopora* sp. The whole series is well-developed in the southern part of the area, but has not been found in the northern part.

UPPER DEVONIAN

Yohlu Sandstone. Thick-bedded, whitish-grey, quartzitic sandstone in the upper part, thin sandstones and shales with bivalves and plants in the middle part, and thick-bedded light grey quartzite in the lower part. It attains a thickness of 300 m. in the northern part of the area, and thins out towards the south, being at the same time replaced by the Hsikuangshan Limestone.

Hsikuangshan Limestone. Thick-bedded bluish-grey limestone in the upper part, and shaly limestone in the lower part which yields *Yunnanella hanburyi* (Dav.), *Y. synplicata* Gr., *Y. triplicata* Gr., *Y.*

abrupta Gr., *Y. quadriplicata* Gr., *Y. uniplicata* Gr., *Y. pentiplicata* Gr., *Y. multiplicata* Gr., *Sinospirifer sinensis* Gr., *Cyrtiopsis* cf. *graciosa* Gr., *C. davidsoni* Gr., *Productella* and *Camarotœchia kinlingensis* Gr. Thickness 150 m.

U. DEVONIAN

Shetienchiao Series. Upper part, shales intercalated with bands of limestone containing *Spirifer tieni* Gr,. *Sinospirifer vilis* Gr., *Sinospirifer tenticulum* (Mansuy), *Atrypa desquamata* var., *Camarotœchia pleurodon* Phill., *Retzia parazyga bifera* (Phill.), *R. parazyga trifera* (Phill.), *Productella* and numerous simple corals; 80-150 m. thick. Middle part, dark grey or blue limestone with *Hypothyridina cuboides*, *Sinospirifer sinensis* Gr. and *Productella*; 30-40 m. thick. Lower part, micaceous sandstone and shale intercalated with thin beds of limestone which contains *Atrypa spinosa*, *Sinospirifer sinensis* Gr., *Productella* and corals; 30-50 m. thick. *Manticoceras* occurs in this series.

MIDDLE DEVONIAN

Shihyenpu Series. This series is subdivided into three parts:—

Upper, or the **Lungkouchung Beds.** Sandstones and shales with a few beds of limestone in the upper and middle parts containing *Atrypa desquamata* var., *Sinospirifer sinensis* mut., *Productella* and *Cyathophyllum*. Thickness about 160 m.

Middle, or the **Chitzuchiao Limestone.** A thick-bedded light grey limestone having a thickness of no less than 300 m. Besides numerous stromatoporoids of the *Clathrodictyon* type, *Stringocephalus burtini* mut., *Atrypa desquamata* Sow., *Gypidula*, and *Tentaculites* occur.

Lower, or the **Shehushan Sandstone.** Quartzitic sandstone and quartzite intercalated with shales in the lower part. Thickness about 100 m.

Tiaomachien Series. Upper part mainly consisting of greenish-yellow and grey shales with beds of shaly limestone, 300-400 m. thick. The limestone beds tend to increase in frequency towards the south-western part of the area. Fossils: *Protolepidodendron*, *Leptostrophia mccarthyi* Gr., *Stringocephalus burtini* var., *Emanuella takwanensis* (Kayser), *Solenospira pagodiformis* Gr., *Atrypa peshuiensis* Gr., *Schizophoria striatula* (Schlotheim), *Atrypa desquamata* var. *hunanensis* Gr., *A. auricurita* Gr., *Rhipidomella* cf. *kutsingensis* Gr., *Spiriferina subcristata* Gr., *Meristella tumidioides* Gr., *Cyrtolitopsis ornatissimus* Gr., *C. subcannasus* Gr., *Gyronema hunanense* Gr., *Pterinea flabelliformis* Gr., *Schizodus sublugonalis* Gr. Lower part, essentially quartzitic sandstones and shales with a basal conglomerate, 100-200 m. thick.

SILURIAN

Tanchiapa Series. Mainly purple shale but occasionally yellowish-green, bluish-grey or light grey in colour, often manganiferous. In the middle and upper parts these shales are intercalated with quartzite and conglomerate of a fine grade and a dark semi-crystalline limestone in which occur *Favosites* and *Clathrodictyon*. Thickness 700-1,000 m.

Tienmashan Series. Light grey shale in the upper part, and quartzitic sandstones and slaty shales in the lower part, about 400 m. Age undetermined.

Chiaotingtze Series. Slaty shales in the upper part, an alternation of slaty shale and argillaceous limestone in the lower part yielding *Tetragraptus tieni* YU, and several species of *Didymograptus*. Exposed thickness no less than 700 m.

(50) KWEICHOW PLATEAU

Well consolidated conglomerate widespread on the surface of the Kweichow Plateau. Age undetermined.

Tzuliuching Series. Red clay-shale with beds of fresh-water limestone in the lower part. Thickness about 250 m. Cretaceous.

Jurassic Sandstone. Coarse-grained yellow sandstone weathering to a brownish colour. Thickness 300 m.

TRIASSIC

Tshin-ngai Beds. Marly deposits containing *Worthenia tuberculifera* KOKEN, *W. nuda* KOKEN, *Pleurotomaria gottschii* KO., *Cœlostylina* cf. *conica* MÜNST., *Loxonema* sp., *Naticopsis signata* KO., *Nucula* cf. *strigilata* GF., *Plicatula sessilis* KO., *Rhynchonella sinensis* KO., *Retzia fuchsi* KO., *Entrochus rotiformis* KO., *Serpula* sp., and *Thamnasteria* (?) sp. indicating some affinity with the St. Cassian fauna.

Paomongchung Limestone. Thin-bedded limestone, grey to black in colour, often laminated in structure with the laminæ usually flexuous or even contorted. In the Lunglih district, central Kweichow, the limestone is full of spheroidal or other irregularly shaped cavities in two horizons. Each cavity is lined with radiating dog-tooth spar, and often filled up with petroleum. The uppermost part of this limestone appears to merge into calcareous shales and marls in the western part of the plateau, and the basal part is composed of a light grey limestone swarming with gastropods in the Anshun district, western Kweichow. A stratum of white and greenish sandy shales or red shales forms the very base. Fossils occur in several horizons, including *Ophiceras* cf. *demissum* OPPEL, *O. sinensis* TIEN, *O. tingi* TIEN, *O.* aff. *chamunda* DIENER, *Pseudosageceras paomochungensis* TIEN, *Clypeoceras vidarbhi* DIENER var. *falciplicatus* TIEN, *Meekoceras kweichowensis* TIEN, *M. evolutus* TIEN, *M. ellipticus* TIEN, *Xenodiscus* cf. *rigida* DIENER, *Pleuronautilus subquadrangulus* TIEN, *Pseudomonotis tenuistriata* BITTNER, and *P.* aff. *decidens* BITTNER. Thickness 1,200-2,000 m.

U. PERMIAN

Yulungshan or Sanchiao Limestone. Whitish-grey, thin-bedded limestone passing into yellow and green shales in the lower part. Fossils occur both in the limestone and the shales. They are: *Beyrichia tingi* PATTE, *Pseudomonotis wangi* PATTE, *P. speluncaria* SCHLOTH., *P.* aff. *griesbachi* BITTNER, *P. teilhardi* PATTE, *Pterinopecten* aff. *rigidus* McCOY, *Protoschizodus* cf. *subæqualis* DE KONINCK, *Pecten* cf. *tenui-*

striata var. *schlotheimi* GIEBEL, *Gervillia* cf. *cuneata* SANDBERGER, *Aviculopecten*, *Modiola*, *Anodontophora*, *Dielasma*, *Phillipsia?* Thickness 120-150 m.

UPPER PERMIAN

Gigantopteris Formation. Shales and sandstones with coal-seams, now and then interstratified with highly fossiliferous limestones of no great thickness. The shales usually yield the *Gigantopteris* flora, while the marine beds contain *Parenteletes sinensis* HUANG, *Orthotichia marmorea* (WAAGEN), *Spinomarginifera pseudosintanensis* HUANG, *Lyttonia nobilis* WAAGEN, *Spiriferina multiplicata* SOW., *S. cristata* var. *octoplicata* SOW., *Uncinulus timorensis* (BEYRICH), *Hustedia indica* (WAAGEN), *Hemiptychina sparsiplicata* WAAGEN, *Notothyris worthi* WAAGEN, *Schuchertella* cf. *semiplana* (WAAGEN), *Schellwienella ruber* (FRECH), *S. acutangula* HUANG, *Productus yangtzeensis* CHAO, *P. gratiosus* WAAGEN, *Lyttonia* cf. *richthofeni* (KAYSER), *Meekella kweichowensis* HUANG, *Pustula* (*Waagenoconcha*) cf. *abichi* (WAAGEN), *Chonetes soochouensis* CHAO, *Oldhamina* cf. *squamosa* var. *anshunensis* HUANG, *Aulosteges poyangensis* var. *medlicotianus* WAAGEN, *Squamularia grandis* CHAO, *Streptorhynchus pelargonatus* var. *lenticularis* WAAGEN, *Striatifera mongolica* (DIENER), and *Athyris timorensis* (ROTHPLETZ). Thickness about 200 m.

Basalt Flow. Thickness 40-250 m.

LOWER PERMIAN

Maokou Limestone. Massive, dark grey limestone with *Neoschwagerina craticulifera* (SCHWAGER), *Doliolina lepida* (SCHWAG.), *Verbeekina verbeeki* (GEINITZ), *Sumatrina annæ* VOLZ, *Wentzelella timorica* (GERTH), *W. flexuosa* HUANG, *Michelinia multiseptata* HUANG and *Waagenophyllum indicum* var. *kweichowensis* HUANG. Thickness less than 100 m.

Chihsia Limestone. Dark-grey to blue limestone often with banded chert arranged along the bedding planes. Fossils: *Tetrapora elegantula* YABE and HAYASAKA, *T. nankingensis* YOH, *Michelinia siyangensis* REED, *M. microstoma* YABE and HAYASAKA, *Wentzelella elegans* HUANG, *Polythecalis yangtzeensis* HUANG, *Stylidophyllum kweichowensis* HUANG, *S. volzi* (YABE and HAYA.), *Monilopora dendroides* YOH, *Corwenia lipoensis*, *Squamularia rostrata* (KUTORGA), *Martinia incerta* TSCHERNYS., *Spirigerella grandis* WAAGEN. Thickness about 300 m.

URALIAN

Wangchiapo Limestone. Massive unfossiliferous limestone at the top, followed by light grey limestone, about 10 m. thick, richly fossiliferous, then by cross-bedded coarse sandstone, thin-bedded limestone and variegated shale of no great thickness. The fossiliferous grey limestone contains *Productus yohi* CHAO, *P.* (*Echinoconchus*) *elegans* MCCOY, *P.* (*E.*) *punctatus* MARTIN, *P.* (*Linoproductus*) *cancriniformis* TSCHERNYS., *P.* (*Krotovia*) *pustulata* KEYS., *Buxtonia kueichouensis* CHAO, *Spirifer orientalis* CHAO, *Choristites abnormalis* CHAO, *Brachythyrina rectangula* (KUTORGA), *Martinia corculum* KUTORGA, *M. re-*

URALIAN.

mota CHAO, *Squamularia asiatica* CHAO, *Pronorites uralensis* var. *shuichengensis* YIN, *Gastrioceras kueichouensis* YIN, *G. orientale* YIN, *G. peronatum* YIN, *G. reticulatum* YIN, *G. yohi* YIN, *G.* aff. *coronatum* FOORD and CRICK, *Gonioloboceras* (*Shuichengoceras*) *yohi* YIN. Equivalent to the Maping Limestone. Total thickness about 45 m.

Maping Limestone. Pure, white limestone partially replaced by shaly limestone towards the northern and eastern parts of the area. Fusulinids abound. The more typical species are: *Parafusulina complicata* (SCHELLW.), *P. japonica* (GÜMBEL), *P. longissima, Pseudofusulina alpina* (SCHELLW.), *P. nathorsti* STAFF and WEDEKIND, *P. acuta* (LEE), *P. tschernyschewi* (SCHELLW.), *P. gregaria* (LEE), *P. prisca* (MÖLLER), *Triticites simplex* (SCHELLW.), *T. contractus* (SCHELLW.), *Schwagerina princeps* EHRENB. Thickness 100-200 m.

M. CARBONIFEROUS

Laokanchai Limestone. Pure limestone with *Staffella sphæroidea* (MÖLLER), *Fusulinella pseudobocki* LEE and CHEN, *Gerthia minor* CHI, *Koninckophyllum tushanense* CHI, *K. trisectum* CHI, *Caninia simpliseptata* CHI, *C. nikitini* STUCKENBERG, *Campophyllum lipoense* CHI, *Clisaxophyllum* sp., *Siphonodendron kweichowense* CHI, *S. reticulatum* LEE and CHU, *Cystophora typica* CHI, *Dibunophyllum tushanense* CHI, *Corwenia chutsingensis* CHI, *Syringopora sinensis* CHI, *Multithecopora yohi* CHI, *Chætetes lungtanensis* LEE and CHU, *C. flexilis* LEE and CHU, *C. raritabularis* LEE and CHU. Thickness up to 200 m.

LOWER CARBONIFEROUS

Shangssu Series. Grey to dark blue limestone, more or less thin-bedded, with quartzose sandstone and black shaly limestone containing bands of chert in the lower part. Fauna: *Yuanophyllum kansuense* YU, *Kueichouphyllum heishihkuanensis* YU, *Lithostrotionella kueichouensis* YU, *Lithostrotion* (*Siphonodendron*) cf. *irregulare* var. *jungtungense* YU, *Dibunophyllum vaughani* GARWOOD and GOODYEAR, *D. minor* YU, *D. platiforme* YU, *Caninophyllum costatum* YU, *D. convexum* YU, *Arachnolasma sinensis* YABE and HAYA., *A. vesiculare* YU, *A. equiseptum* YU, *Cyathophyllum stutchburyi* var. *merophylloides* YU, *Daviesiella llangollensis* DAV., *D. comoides* SOW., *D. productiformis* GR., *D. gigas* GR., *Productus* (*Kansuella*) *maximus* MCCOY, *P.* (*Gigantella*) *tingi* GR., *P.* (*G.*) *giganteus* MART., *P.* (*Kansuella*) *edelburgensis* PHILL., *P. corrugatus* MCCOY, *Chonetes papilionaceus* PHILL., *Martinia shangssuensis* GR. Thickness 130-400 m.

Chiussu Series. Sandstones with shales and shaly or sandy limestones containing *Thysanophyllum asiaticum* YU, *T. pseudovermiculare* (MCCOY) var. *minor* YU, *Siphonodendron curvatum* YU, *Yabeella cyathophylloides* YU, *Syringopora geniculata* PHILL., *S. gracilis* KEYSERLING, *Productus inflatiformis* GR., *P. yunnanensis* LOCZY, *Cryptospirifer orientalis* GR., and *C. tatangensis* GR. Thickness 200-280 m.

Tangpakou Sandstone. Quartzitic sandstone and shaly limestone with a subordinate amount of shale containing *Pseudouralinia irregularis* YU, *P. gigantea* YU, *P. simplex* YU, *P. tangpakouensis* YU,

L. CARBONIFEROUS

Rhipidomella michelini L'EVEILLÉ, *Leptæna analoga* PHILL., *Productus præmanchuricus* GR., *Neoproductella tangpakouensis* GR., *Athyris* (*Cleiothyridina*) *profundisinosus* GR., and *Spirifer chichaensis* GR. Thickness 170-190 m.

Kolaoho Series. Thin-bedded shaly limestone intercalated with black shale containing *Cystophrentis kolaohoensis* YU, *C. pinnatea* YU, *Camarotœchia kinlingensis* GR., *Martiniella nasuta* GR., *Neoproductella tenuistriata* GR., *N. kolaohoensis* GR., *Eochoristites neipentaiensis* CHU, and *Spirifer subduplicosta* GR. Thickness 280 m.

U. DEVON.

Maochai Series. The upper part of this series is named the **Yaoso Limestone,** 38 m. thick, and has so far yielded no fossils. The lower part, or the **Wangchengpo Group,** contains *Sinospirifer sinensis* GR., *Schizophoria macfarlanii* MEEK, *Reticularia maureri* HOLZAPFEL, and *Cryptonella whidborni* (DAV.). Total thickness 630 m.

MIDDLE DEVONIAN

Tushan Group. This group comprises four members. The **Chiwochai Limestone** with *Stringocephalus burtini* DEFR., *Productella productoides* var. *sinensis* GR., *Plectospirifer takwanensis* (KAYSER), *P. heimi* GR., *Reticularia tushanensis* GR., *Atrypa desquamata* SOW., *A. desquamata* var. *auriculata* HAYA., *Lophospirina angustipegmatis* GR. and *Hormatoma tushanensis* GR. Thickness 180 m.

The **Sungchiachiao Sandstone.** Thickness 120 m.

The **Chipao Limestone** with *Stringocephalus obesus* GR., *S. magnoseptatum* GR., *S. latus* GR., *Atrypa aspera* var., *Athyris vittata* var. *antecedens* GR., *A.* cf. *concentrica* v. BUCH, *A. stringocephaliformis* GR., *Emanuella takwanensis* (KAYSER), *Reticularia* cf. *maureri* (HOLZAPFEL), *Spirifer platysellus* GR., *Plectospirifer fongi* GR., *Schizophoria striatula* (SCHLOTH.), *Productella productoides* var. *sinensis* GR., *Chonetes orientalis* LOCZY, *Uncites* sp., *Favosites* sp., and *Pachypora* sp. Thickness 180 m.

The **Pangchai Sandstone** occupies the lowest position. It is a fine, argillaceous sandstone, about 150 m. thick, yielding *Leptostrophia mccarthyi* GR., *Atrypa*, *Schizophoria* and *Spirifer*. Thickness 150 m.

The Silurian is represented in Kweichow generally by a yellowish shale which, in the central part of the plateau, is overlain by a limestone crowded with *Spirifer* (*Eospirifer*) *tingi* GR. This characteristic Upper Silurian species is associated with *Favosites forbesi* E. and H. var. *kueitungensis* GR., *Omphyma glomerata* GR., *O. cystiphylloides* GR., *Cystiphyllum omphymiforme* GR., and *Amplexus* cf. *lojopingensis* GR.

M. ORD.

Orthoceras Limestone. Thickness 80-100 m.

Neichiashan Series with *Yangtzeella poloi* (MARTELLI).

M. Ordovician

Lesueurilla Limestone containing *Lesueurilla meitanensis* Yu, *Eccyliopterus sinensis* (Frech), and *Cameroceras tenuiseptum* var. *ellipticum* Yu.

Meitan Shale. Greenish shale with *Phyllograptus wulipoensis* Yu.

The total thickness from the top of the Neichiashan Series to the bottom of the Meitan Shale amounts to 180-200 m.

L. Ord.

Ichang Limestone. Thickness reported to be considerable, but the exact figure is unknown. *Cameroceras fœrstei* Yu occurs in the uppermost part of this limestone.

(51) Eastern and Central Yunnan

Lacustrine Clays with layers of lignite and fresh-water gastropods largely belonging to the family Viviparidæ. Thickness more than 50 m. Probably Pliocene.

Hopachung Series. Fine sandstone, black slate and friable yellow shale with lenticular seams of coal and beds of conglomerate. Pelecypods and plant remains occur in the yellowish clay-shale and carbonaceous shale near the coal-seams. Thickness 1,000 m.; well-developed in the Kochiu district.

In northern Yunnan a series of similar coal-bearing beds is well exposed in the Chinyaping (lat. 26° 36′ N., long. 101° 13′ E.) and Taipingchange districts, east of Yungpeihsien. There the coal-bearing shales contain *Cladophlebis ræsserti* Presl, *Ctenopteris*, *Tæniopteris* aff. *T. immersa* Nath., *Glossopteris indica* Schimper, *Dictyophyllum exuile* Brauns., *Clathropteris platyphylla* Goeppert, *Pterophyllum* aff. *longifolium* Brongn., *Anomozamites inconstans* Brauns., and *Ptilophyllum acutifolium* Morris. Probably Rhætic or Liassic.

Triassic

Chakoulou Beds. Mainly shales containing *Paratibetites clarkii* Mans. and *P. tuberculatus* Mans., probably belonging to the Norian Stage.

Marls and Sandstones with *Trachyceras fasciger* Mans., and *T. costulatum* Mans., believed to represent the upper Ladinian Stage.

Kochiu Limestone. Generally well-bedded, but occasionally massive limestone, alternating with marls and sandstones in certain facies. Fauna: *Myophoria szechenyi* Loczy, *M. radiata* Loczy, *M. inæquicostata* Klips., *M.* cf. *lævigata* Gf., *M.* cf. *curvirostris* Schloth., *Lima chinensis* Loczy, *Ostrea* (*Terquemia*) *difformis* Gf., *Nucula excavata* Münst., *Pseudomonotis* cf. *illyrica* Bittner, *P. plicatuloides* Mans., *Meekoceras yunnanensis* Mans., *Trachyceras* sp., *Halobia* cf. *comata* Bitt., *Spiriferina subfragilis* Loczy, *Terebratula (Cœnothyris) vulgaris* Schloth., *Encrinus liliiformis* Lamarck. In the Kochiu district the limestone is quite pure, and its thickness is estimated at no less than 1,500 m.

Triassic

Kintung Shale. Purple and greenish shales with beds of sandstones and grit and lenticular layers of limestone which carry *Myophoria elegans* Dunker?. Rock salt and gypsum also occur in this series. Basal conglomerate occasionally present. Thickness over 1,000 m.

[Note.—This Triassic succession must be accepted with reserve, for the fossils have been collected by different observers and at different times.]

Thin-bedded Limestone. Only developed in the northern part of the area.

Coal-bearing Shale. Only developed in the northern part of the area, yielding *Gigantopteris nicotianæfolia* Schenk, *Neuropteridium polymorphum* Halle, *Pecopteris arcuata* Halle, *P.* aff. *hemitchoides* Brongn., *Lobatannularia* cf. *maxima* (Schenk) Sze, *Tæniopteris abnormis* Gutbier, *Sigillaria acutangula* Halle, *Ptychocarpus tingi* Halle and *Dictyophyllum.*

Permian

Basalt Flows. 50-100 m. thick in the southern part of the area, but reaching more than 1,000 m. in the Hueili district.

Maokou Limestone. Dark blue to dark grey limestone with abundant *Neoschwagerina, Verbeekina, Doliolina, Sumatrina* and other highly developed fusulinids. In the Lunan district this limestone forms hosts of fantastic pinnacles recalling the scenery of the Karst country.

Chihsia Limestone. Dark limestone with *Nankinella, Eoverbeekina, Parafusulina, Tetrapora elegantula* Yabe and Haya., *Stylidophyllum volzi* (Yabe and Haya.) and *Michelinia* cf. *microstoma* Yabe and Haya. This, together with the Maokou Limestone, attains a thickness of about 350 m.

Uralian

Maping Limestone. Pure limestone, white or pinkish in colour, often globulitic in structure, containing *Schwagerina princeps* (Ehrenb.) and other fusulinids of the Uralian Stage; well-developed in the Anning and Kienshui districts in central Yunnan, some 30-150 m. thick, but partly replaced in the Chutsing district, north-eastern Yunnan, by shales and sandstones.

M. Carb.

Weining Limestone. Pure, white limestone with *Cribrostomum longissimoides* Lee and Chen, *Schubertella magna* Lee and Chen, *Bradyina nautiliformis* Möller, *Fusulinella bocki* Möller, *Staffella sphæroidea* (Möller), *S. ozawai* Lee and Chen, *Fusulina cylindrica*

M. CARBONIFEROUS

FISCHER DE WALDHEIM, *Wedekindella* sp., *Koninckophyllum tushanense* CHI, *K. trisectum* CHI, *Caninia simpliseptata* CHI, *C. nikitini* STUCKENBERG, *Campophyllum lipoense* CHI, *C.* cf. *vigilans* REED, *Dibunophyllum tushanense* CHI, *D. weiningense* CHI, *Corwenia chutsingensis* CHI, *Multithecopora yohi* CHI, *Chætetes raritabulatum* LEE and CHU, *C. changyiensis* CHI, *Squamularia asiatica* CHAO, *Cleiothyridina trigonalis* GR., *Athyris geradiformis* GR., *Buxtonia scabricula* (MARTIN), *Cryptospirifer* sp., *Spirifer (Choristites) weiningensis* GR. (closely related to *Choristites mosquensis*), and *Choristites mansuyi* CHAO. Thickness 30-150 m.

L. CARBONIFEROUS

Shangssu Series. Limestones, sandstones and shales, some 56 m. in the northern part of the area, but thinning out towards the south. Fossils: *Productus (Gigantella) edelburgensis* PHILL., *P. (G.) giganteus* MARTIN, *P. (G.) tingi* GR., *P. (G.) maximus* MCCOY, *P. (Striatifera) groberi* (KRENKEL), *P. tenuistriatus* VERNEUIL, *Athyris (Cleiothyridina) ingens* DE KONINCK, *Buxtonia scabricula* (MARTIN), *Chonetes papilionaceus* PHILL., *Daviesiella comoides* (SOW.), *D. llangollensis* DAV., *Kueichouphyllum sinensis* YU, *K. heishihkuonense* YU (a genus related to *Palæosmilia*), *Thysanophyllum* and *Yuanophyllum*.

Eulkai Series. Sandstones and shales with coal-seams. Thickness 20-70 m.

Kolaoho Series. Thin-bedded, dark blue limestone in certain facies, and shales and shaly sandstones with thin beds of limestone in others. *Pseudouralinia, Syringopora* of the type of *S. ramulosa, Composita globularis* PHILL., *Martiniella nasuta* GR., and *Eochoristites neipentaiensis* CHU are common fossils. Thickness 72-88 m.

UPPER DEVONIAN

Sinospirifer triplisinosus Beds. A dark limestone with *Productella subaculeata* (MURCH.) mut., *Yunnanella synplicata* GR., *Y. mesoplicata* GR., *Sinospirifer gortanii* (PELLIZZARI), *S. vilis* GR., and *Cyrtiopsis graciosa* GR. probably belongs to this stage.

Sintsouen Beds. The fauna contained in this formation, as described by Mansuy, consists of *Productella bourguignoni* MANSUY, *Spirifer verneuili* var. *yunnanensis* MANS. [=*S. yunnanensis* GR.], *Pugnax pugnus* (MARTIN) [=*P. pugnus* var. *sinensis* GR.], *Camarotœchia convexa* MANS., *Anastrophia proxima* MANS.

Laofongtsun Beds. Characterized by *Atrypa aspera* SCHLOTH., *Cyrtina heteroclita* DEFR., and *Bellerophon striatus* FERUS and VERNEUIL.

Lunan Beds. Fauna: *Spiriferina cristata* var. *octoplicata* SOW., *Uncites gryphus* SCHLOTH., *Modiomorpha duponti* MANS., *Pleurotomaria delphinuloides* SCHLOTH., *Murchisonia loxonemoides* WHIDBORNE, *M. bigranulosa* VERNEUIL, *M. angulata* PHILL., *M. margarita* WHIDB., *Natica antiqua* GOLDFUSS, *Macrochilina arculata* SCHLOTH.

Kwahsinshan Formation. Mainly limestone, light and dark blue in colour, sometimes argillaceous in composition, with *Stringocephalus burtini* DEFR., *Atrypa desquamata* var. *auriculata* HAYASAKA, *A.* cf. *richthofeni* (KAYSER), *Schizophoria striatula* SCHLOTH., *Rhipidomella chutsingensis* GR., *Emanuella takwanensis* (KAYSER), *E. takwanensis* var. *pentagona* GR., *Tingella reticularioides* GR., *Athyrisina plicata* (MANSUY), *A. biplicata* GR., *A. uniplicata* GR., *Athyris vittata* HALL?, and *A. vittata* var. *intermedia* GR.

Tahili Beds. The fauna from this formation comprises *Cyathophyllum lantenoisi* MANS., *C. douvillii* FRECH, *Douvillina interstrialis* (PHILL.), *Spirifer tenticulum* MANSUY, *S. curvatus* SCHLOTH., *Atrypa desquamata* SOW., *A. arimaspus* (EICHW.), *A. douvillii* MANS., *A. bodini* MANS., *Conchidium acutilobatum* SANDBERGER, *Rhynchonella huatina* MANS., *R. letiensis* MANS., and *R. gigantea* MANS. After a brief review of this fauna, as described by Mansuy, who holds it to be an Upper Devonian representative, Grabau relegates it to the Middle Devonian.

MIDDLE DEVONIAN

Tungshan Limestone. The fauna contained in this limestone comprises *Crania obsoleta* GOLDFUSS, *Rhipidomella chutsingensis* GR., *Schizophoria excellens* GR., *S. macfarlanii* (MEEK) var. *kansuensis* GR., *S. striatula* SCHLOTH. mut., *S. striatula* var. *quadrangularis* GR., *Stringocephalus obesus* GR., *Atrypa desquamata* var. *auriculata* HAYASAKA, *A. aspera* SCHLOTH., *Plectospirifer takwanensis* (KAYSER), *Emanuella plicata* GR., *Meristella chutsingensis* GR., *M. flayellii* MANS. and *M. tumidioides* GR.

Sieul Beds. The fauna comprises *Calceola sandalina* LAMARCK, *Cystiphyllum vesiculosum* PHILL., *Cyathophyllum helianthoides* GOLDFUSS, *Meriophyllum poshiense* MANS., *Productella productoides* DAV. var. *sinensis*, and *Meristella flayellii* MANS.

Lunghuashan Sandstone. Thickness 20-200 m.; apparently thinner in the southern part of the area; contains *Arthrostigma gracile* DAWSON.

SILURIAN

Miaokao Group. Largely thin-bedded limestones intercalated in shales with fish-beds near the top. *Leperditia* also fairly abundant. The limestones yield *Cladopora kutsingensis* GR., *Camarotœchia* cf. *tonkinensis* MANS., *Spirifer tingi* GR., *Poleumita changyiense* GR., *Hormatoma chutsingensis* GR., *Holopea yilungense* GR., *Actinopteria mansuyi* GR., *Pterinea mientienensis* GR., and *Modiolopsis miaokaoensis* GR. An assemblage of crustacea such as *Sinocaris asiatica* MANS., *S. barbagii* MANS., *Ceratiocaris pierloti* MANS., together with *Spirifer bourgeoisi* MANS., *Orbiculoidea sinensis* MANS., *Leda circumflexa* MANS. and *Goniophora contraria* MANS., represents another facies of the fauna.

SILURIAN

Mientien Group. Shales, sandstones and limestones, typically exposed in the Chutsing region, and characterized by the presence of *Lingulella cuneatiformis* GR. and *Modiomorpha crypta* GR.; underlain by beds with *Favosites* and *Syringopora* and graptolites. The graptolite-bearing shale, more than 70 m. thick, is divisible into two zones. The higher zone contains *Monograptus sedgwicki* PORTLOCK, *M. lobiferus* McCOY, *M. tenuis* PORTLOCK, *M. leptotheca* LAPW., *M. atavus* JONES, *M. jaculum* LAPW., *M. concinnus* LAPW., *M. gemmatus* BARR., *Glyptograptus serratus* E. and W., *G. nicertus* E. and W., *Climacograptus scalaris* HIS., *Gladiograptus perlatus* NICH., and *Mesograptus magnus* LAPW. The lower zone yields *Monograptus incommodus* TÖRNQ., *M. regularis* TÖRNQ., *M. tenuis* PORTLOCK, *Climacograptus rectangularis* McCOY, *C. törnquisti* E. and W., and *Mesograptus modestus* LAPW.

CAMBRIAN

Higher Cambrian Beds are only developed in the southernmost part of the area and consist of an alternation of limestones and sandy shales. The presence of Upper Cambrian is indicated by *Billingsella, Eoorthis, Huenella, Chuangia, Crepicephalus* and *Ptychaspis*, and of Middle Cambrian by *Acrothele, Obolus, Agnostus, Anomocare, Blackwelderia, Conocephalina, Coosia, Damesella, Drepanura* and *Stephanocare*.

Lower Cambrian. Shales and sandstones of yellow or orange colour, occasionally marly, with *Redlichia carinata* MANS., *R. chinensis* WALCOTT, *Palæolenus douvillii* MANS., *Acrothele orbicularis* MANS., *Obolus*, and *Lingula*; typically developed in the Yiliang district. Thickness over 300 m.

Arkose Sandstone about 300 m. thick or more; age uncertain.

SINIAN?

Kaoliang Series? Slates, phyllites, quartzites and sandstones with lenticular beds of limestones, mostly purplish in colour, thousands of metres thick; well exposed along the southern extension of the Ailao Range and eastern slope of the Wuliangshan between the Red River and the Lantsangkiang.

WUTAI OR ARCH.

Wuliang Complex. Gneisses and schists alternating with light and dark coloured bands of quartzose and amphibolitic rocks, forming the northern part of the Ailao Range and the western slope of the Wuliangshan, and extending beyond the Yunghsien and Shunning districts.

(52) SOUTH-WESTERN KUANGSI

Nanning Series. Soft, friable clay-shales, clays and soft sandstones containing seams of lignite. Plant remains and fresh-water shells abound in places. The fauna comprises *Hyriopsis arcidens* ODHNER, *Rhombunio ellipticus* ODH., *R. ventricosus* ODH., *R. spinifer* ODH., *Psilunio tuberosus* ODH., *Pyrgula sinensis* ODH., *Oncomelania* and numerous gastropods belonging to the genera *Stenothyra, Tolu-*

toma, Paracampeloma and *Melania.* Thickness about 50 m.; well-developed in several basins along the Sikiang and the Ningmingho valleys.

Red Sandstone. Typically developed in the Nanning Basin. Thickness and age unknown; probably early Tertiary.

CRETACEOUS?

Fuhpo Series. Upper part, arkose sandstone, conglomeratic at intervals, followed downward by variegated sandstones and shales, those of purple colour predominating; middle part, a series of tuffs generally of purplish-red colour with numerous crystals of felspar and round grains of quartz; rhyolite forms the basal part of the series. Total thickness 1,000-2,000 m. The high mountain ranges between Kuangsi and Annam are largely composed of this series.

TRIASSIC

Pingerhkuan Shale. Dark green shale, now and then sandy and occasionally intercalated with sandstone. Thickness over 1,000 m.

Pingtsiang Limestone. Upper part, thick-bedded, white limestone with abundant spherules showing concentric structure; about 250 m. thick; lower part, thin-bedded limestone, 200-300 m.

U. PERMIAN

Gastrioceras Beds. Argillaceous limestone interstratified with shales. Lamellibranchs flourish in the shales and *Gastrioceras* in the limestone.

Gigantopteris Formation. Greenish-yellow, purple and black shales, sometimes siliceous and sometimes sandy. *Oldhamina, Gastrioceras, Walchia, Tæniopteris* and *Gigantopteris* occur in alternating layers. Occasionally *Gastrioceras* and leaves of plants occur in superposition on the surface of a single slab. A highly ferruginous shale is often present at the base. Thickness 30-80 m.

L. PERMIAN

Maokou Limestone. Light grey limestone, often lumpy, and sometimes thick-bedded, containing a few flints. Fossils: *Cancellina schellwieni* DEPRAT, *Verbeekina verbeeki* GEINITZ, *Neoschwagerina craticulifera* (SCHWAGER), *N. simplex* OZAWA, *N. minoensis* DEPRAT, *Pseudodoliolina ozawai* YABE and HANZAWA, *Doliolina lepida* (SCHWAGER), *Sumatrina annæ* VOLZ, *Pseudofusulina douvillei* COLANI, *Parafusulina japonica* GÜMBEL?, *Lyttonia richthofeni* (KAYS.). Thickness about 50 m.

Thin-bedded, impure limestone with bands of chert, probably equivalent to the Chihsia Limestone.

Chuanshan Limestone. Light to dark grey limestone, well-bedded, with a few flint-concretions, rich in corals and fusulinids. The latter belong exclusively to the Uralian. The leading fossils are: *Pseudofusulina prisca* (MÖLLER), *Triticites parvulus* (SCHELLW.), *Quasifusulina longissima* (MÖLLER), *Schwagerina princeps* EHRENB. Only the upper part of this limestone is exposed in the Shangkin and Lungchou districts.

(53) Western Yunnan

Lava Flows. Black, slaggy lavas connected with craters which present a recent appearance. In certain districts, *e.g.*, Kungpo, these lavas are spread out over the lacustrine deposits. Probably late Pliocene or early Pleistocene.

Lacustrine Deposits. Gravels, sands and clays with layers of lignite or peat or carbonaceous shale containing fresh-water shells referable to *Bithynia, Margarya* and other modern genera. Well-developed in the Kangai (lat. 24° 47′ N., long. 98° 8′ E.) and Nantien (lat. 24° 49′ N., long. 98° 22′ E.) Plains, about 1,000 m. above sea level.

Trachy-andesite. Massive lavas of light-grey colour sometimes with a well developed pumice-like structure.

Bedded Andesite. Ash-grey, greyish-blue and occasionally reddish-grey, close-grained porphyritic andesites, often showing bedded or platy structure. Probably Cretaceous.

Triassic Shales and Limestones. Limestones appear to prevail in the upper part, greenish or yellowish shales with occasional bands of limestone in the lower part. This formation has yielded, at various horizons and localities, the following species: *Lima* cf. *telleri* Bittn., *L.* aff. *austriaca* Bittn., *Mysidioptera* cf. *incurvistriata* Gümb., *M. paucicostata* Reed, *Gervillia krumbecki* Reed, *G.* aff. *planata* Broili, *G. præcursor* Quenst., *Cassianella* cf. *verbeeki* Krumb., *C.* cf. *gryphæata* Münst., *C.* cf. *bidorsata* Münst., *Halobia* aff. *tropitum* Kittl, *Cucullæa* (*Macrodon*) cf. *impressa* Münst., *Leda* [*Nuculana*] *yunnanensis* Reed, *L.* [*N.*] *perlonga* Mans., *Nucula strigillata* Gf., *N. misolensis* Jaworski, *N. subobliqua* d'Orb., *Palæoneilo præacuta* Klips., *Cardita* cf. *buruca* Boehm, *C. globiformis* Boettger var., *C.* cf. *trapezoidalis* Krumb., *Myophoria verbeeki* Boettg. var., *M.* cf. *volzi* Frech, *M.* aff. *fissidentata* Wöhrm., *Trachyceras* (*Sirenites*) sp., *Cœlostylina* aff. *heeri* Kittl, *Scurria delicata* Reed, *Pinna* aff. *lima* Boehm, *Encrinus liliiformis* Lamarck, *Protrachyceras ladinum* Mojs., *Pecten* aff. *subalternans* d'Orb., *Posidonia* cf. *wengensis* Wissm., *Daonella* cf. *lommeli* Wissm., *Thecosmilia* aff. *fenestrata* Reuss. Well exposed west of Puerh.

Plateau limestone. Limestones associated with shales, tuffs, and contemporaneous lava flows. Probably Permian.

L. Silurian

Shihtien Slate. Upper part: tough, fine-grained, greenish-grey or pinkish flaggy slate with *Monograptus lobiferus* McCoy, *M. sedgwicki* Portl., *M. tenuis* Portl., *M. leptotheca* Lapw., *M. atavus* Jones, *M. jaculum* Lapw., *M. concinnus* Lapw., *M. gemmatus* Barr., *Glyptograptus serratus* E. and W., *G. incertus* E. and W., *Climacograptus scalaris* His., *Gladiograptus perlatus* Nich., and *Mesograptus magnus* Lapw. Lower part: tough, rather coarse-grained, carbonaceous and

L. SIL.

micaceous shales or black slates with *Monograptus incommodus* TÖRNQ., *M. regularis* TÖRNQ., *M. tenuis* PORTL.?, *Climacograptus rectangularis* McCOY, *C. tornquisti* E. and W., and *Mesograptus modestus* LAPW.? Total thickness 23 m. as developed in the Shihtien district (lat. 24° 45′ N., long. 99° 12′ E.).

M. ORDOVICIAN

Yungchang Formation. Largely grey or greenish-grey limestones, sometimes shaly, intercalated with nodular marls and dark-grey or black shales, richly fossiliferous. Neither the sequence of the rocks nor their thickness can be determined with certainty on account of their disturbed condition. Those exposed in the Shihtien section appear to amount to more than 200 m. Fauna: *Sinocystis loczyi* REED, *S. yunnanensis* REED, *S. piroides* REED, *Ovacystis mansuyi* REED, *Eucystis* cf. *raripunctata* (ANG.), *Echinosphæra asiatica* REED, *E. sinensis* REED, *Sphæronis lobiferus* REED, *S. shihtienensis* REED, *Heliocrinus fiscella* BATHER, *H. qualus* BATHER, *H. subovalis* REED, *H.* cf. *balticus* EICHW., *Camarocrinus asiaticus* REED, *Philhedra sinensis* REED, *Hemipronites giraldi* (MARTELLI) var. *yunnanensis* REED, *Orthis prætor* REED, *Rafinesquina* sp., *Asaphus* aff. *expansus* (LINN.), *Illænus excoides* REED, *I.* aff. *oblongatus* ANG., *I.* aff. *schmidti* NIESZK, *I.* aff. *punctulosus* SALT., *Lichas* (*Metopolichas*) *celorhin* (ANG.) cf. var. *coniceps* LEUCHT, *Calymene* sp., *Holopea* sp., *Bellerophon* (*Sinuites*) cf. *rugulosus* KOKEN, *Endoceras wahlenbergi* FOORD, *E.* cf. *cancellatum* (EICHW.), *E.* aff. *reinhardi* (BOLL), *Orthoceras regulare* SCHLOTH., *O.* cf. *kinnekullensis* (FOORD), *O.* cf. *scabridum* (ANG.), *O.* (*Protocycloceras?*) *deprati* REED, *Actinoceras* cf. *bigsbyi* BRONN, *Trocholites yunnanensis* REED, *T.* aff. *macromphalus* (SCHRÖD.), *Lituites* sp. The black shale or slate extends to the Paima Valley about 10 miles south of Shihtien. In the Pupiao district (about lat. 25° 2′ N., long. 99° 6′ E.) the Ordovician is represented by hardened shales, reddish-yellow or greenish-grey in colour, occasionally rather sandy, with bands of nodular limestone, and in the Lameng district by dark-red calcareous mudstones. These localities have yielded *Didymograptus murchisoni* (BECK), *D. murchisoni* var. *geminus* (HIS.), *D. indentus* (HALL), *Climacograptus* cf. *scharenbergi* LAPW., *Echinosphæra* cf. *aurantium* (GILL.), *Echinoencrinus* sp., *Caryocrinus* cf. *turbo* BATHER, *Orthis prætor* (REED), *Hyolithes* cf. *clivii* REED, *H.* cf. *loczyi* REED, *Ogygites yunnanesis* REED, *Illænus* cf. *esmarki* SCHLOTH., *I.* cf. *tauricornis* KUT., *Nileus armadillo* DALM., *Bathyurus mansuyi* REED, *Lichas* aff. *verrucosus* EICHW., *Calymene unicornis* REED and *Pliomera martellii* REED.

Kaoliang Series. White quartzites and fine-grained phyllites typically exposed in the neighbourhood of Huanhsipo between the Taho and the Kuyungho.

Archæan. Gneisses, mica schists and occasional bands of crystalline limestone, associated with large masses of granites, widely exposed around Tengyueh and in the region to the west of it.

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